

Canada

Manitoba

# ASSINIBOINE RIVER FLOW ENHANCEMENT



## SHELLMOUTH RESERVOIR WATER SUPPLY STUDY

Winnipeg, Manitoba

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## Executive Summary

In response to water supply concerns along the Assiniboine River during the drought years 1988 and 1989, PFRA and Manitoba Water Resources jointly carried out a study of the feasibility of increasing the water supply capability of the water storage currently available behind the Shellmouth Dam. This reservoir, created in 1969, is presently used for a variety of purposes, most notably flood damage reduction downstream of the dam, flow augmentation during low flow periods, fisheries, and recreation.

The study began with an initial phase in which operational alternatives capable of increasing the reservoir's water supply capability were identified and evaluated in preliminary fashion. Through this process, two scenarios, one of which would involve installation of gates on the currently ungated spillway, were selected for detailed analysis of their water supply capability and also the hydrologic and environmental impacts that they would lead to. The scenarios were named "Modified Base" and "Gated 1".

Evaluation of these scenarios and the existing conditions (Base Scenario) was largely carried out using a computer-based simulation model of the hydrologic regime of the main stem of the Assiniboine River. The simulations covered a historic period from 1913 to 1990; they were based on historic or developed flow arrays adjusted for known water usage; and they considered current and estimated future (for a 50-year time horizon) water demands along the river. Also considered in the study were the water supply implications of Saskatchewan using its share of flows originating in the Saskatchewan portion of the Upper Assiniboine River Basin, and of removing Manitoba Hydro's current minimum flow requirement for cooling purposes at the Brandon Thermal Generating Station.

Based on the work done in this study it was concluded that:

- Creation of the Shellmouth Reservoir has greatly changed the flow characteristics of the Assiniboine River in Manitoba. Flood flows have been reduced to the point where flooding is no longer a major problem along the river. Conversely, low flows have been augmented such that minimum flows of  $5.66 \text{ m}^3/\text{s}$  can be maintained at Brandon for cooling purposes at Manitoba Hydro's thermal generating station,  $2.83 \text{ m}^3/\text{s}$  can be maintained for instream purposes at Headingley, and in addition to the above minimum flows,  $132\,000 \text{ dam}^3$  could be provided annually on an assured basis for consumptive uses. Since it was created, the reservoir has never been stressed from a water supply perspective;
- With the Shellmouth Reservoir as presently operated, only 48% of the Assiniboine River's assured consumptive water supply capacity of  $132\,000 \text{ dam}^3$  has been licensed for consumptive use. An additional  $68\,000 \text{ dam}^3$

could be allocated before this capacity, as defined by the Reservoir's existing operating regime and inflows and weather conditions such as existed during the most severe drought on record (1937-42), would be fully utilized;

- Changing the reservoir's operating regime as studied herein would increase the Assiniboine River's assured annual water supply capability by 12 000 dam<sup>3</sup>. Such an operating change would allow the projected future demands to be met without lowering the reservoir beyond what current demands would require if the 1937 to 1942 drought were to occur;
- The operating regime changes would result in some loss of downstream flood damage reduction benefits. These could for the most part be recovered through the retrofitting of gates on the currently ungated spillway. This was found to be technically and hydraulically feasible, and would cost in the range of one to two million dollars;
- The operating regime changes would have little impact on existing recreation development along the reservoir shoreline. They could however increase the frequency and duration of backwater effects in the Kamsack, Saskatchewan area and of at or near bankfull flows below the dam. This could result in increased local drainage difficulties both above and below the reservoir;
- Mercury concentrations in fish in the reservoir are at present near or in excess of limits allowed for human consumption. The operating regime changes investigated could contribute to a temporary increase in these levels. Given the current state of knowledge concerning this issue, quantitative assessments of this possibility could not be made. The reservoir's fishery could also be negatively affected by impacts on historic spawning areas and increased nutrient loadings. These would likely be most pronounced for Gated 1. The reservoir's increased water supply capability could lead to augmented river flows, resulting in an enhancement of the aquatic environment along the river in Manitoba;
- Although very unlikely, should Saskatchewan develop sufficient storage to make use of its 50% share of Upper Assiniboine runoff originating in Saskatchewan, the Shellmouth Reservoir would, under current consumptive demands and minimum flow requirements at Brandon and Headingley, be drawdown to about elevation 418.5 m for both the Base and Modified Base operating modes. While this would lead to some operating difficulties, it is likely that the reservoir could successfully be lowered to this elevation, particularly during drought periods when adverse conditions are anticipated. Reducing the minimum flow requirement at Brandon to 2.83 m<sup>3</sup>/s would sufficiently increase the amount of water available for consumptive purposes that, even with Saskatchewan using its flow apportionment, the estimated future demands of 117 000 dams<sup>3</sup> could be met on an assured basis with existing operating rules.

On the basis of the work done in this study, and on the above conclusions, it is recommended that:

1. A public information program be undertaken to:
  - inform residents along the Assiniboine River of its important role in southern Manitoba, and how the Shellmouth Reservoir has changed its flow regime;
  - explain how and why the reservoir is presently operated;
  - present the findings of this study concerning the river's water supply capability and how it might be increased.
2. A water monitoring program be implemented to obtain data on actual water usage from the river and to ensure that all major usage is licensed and that licences are adhered to.
3. Manitoba Water Resources consider establishing an Advisory Board which represents existing and potential users of Assiniboine River water to facilitate local input into water management along the Assiniboine River.
4. Mercury concentrations in fish in the reservoir continue to be monitored, and the bio-physical mechanisms of mercury production and uptake continue to be studied.
5. Should additional water supplies be required along the Assiniboine River and the Modified Base or Gated 1 operating regimes be considered, additional studies should be carried out to:
  - examine in more detail the environmental issues identified in this report;
  - develop a solution, including possible purchase of affected lands, to perceived drainage problems in the Kamsack, Saskatchewan area;
  - explore further the retrofitting of spillway gates, particularly with regard to operating considerations and annual operating and maintenance costs.

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# Introduction

## General

The Assiniboine River is southern Manitoba's most important watercourse. It drains an area of approximately 160 000 km<sup>2</sup>; of which 90 000 are in Saskatchewan, 20 000 in the United States, and the remainder in Manitoba. As shown in Figure 1, the river flows in a predominantly southeasterly direction, passing through the major urban centres of Brandon and Portage la Prairie before joining the Red River in Winnipeg.

Historically, the Assiniboine River has experienced a wide range of flows. At Brandon, the historic mean daily low is 0.2 m<sup>3</sup>/s recorded in 1942, while the historic mean daily high is 650 m<sup>3</sup>/s recorded in 1923. Since the early 1970s, the river's flows have been regulated by storage with the 477 000 dam<sup>3</sup> Shellmouth Reservoir located near the Town of Russell. Since its creation, this reservoir has been operated in a multi-purpose mode to serve a variety of needs. It provides downstream flood reduction up to and including the City of Winnipeg; municipal water supplies for the cities of Brandon and Portage la Prairie; industrial needs such as the Simplot fertilizer plant in Brandon; cooling for Manitoba Hydro's Brandon Thermal Generating Station; domestic and agricultural needs (including irrigation) along the entire river; agricultural, rural and domestic needs in the La Salle River Basin (via Assiniboine to La Salle diversions constructed in the early 1980s); and waste assimilation in the City of Winnipeg. In addition, the reservoir itself has developed into a valuable recreation and fisheries resource.

In addition to these existing demands, a variety of potential new demands for Assiniboine River water have recently been identified. These include a proposal by the Pembina Valley Water Co-Op to divert up to 0.57 m<sup>3</sup>/s to the western part of the Red River Valley for municipal, industrial, rural domestic and livestock uses, and a desire by producers in the Portage la Prairie area to substantially increase irrigated production of fruit, vegetables, and potatoes.

Because of the Assiniboine River's importance to southern Manitoba, and because of the increasing demands being placed on it, the 1988 drought raised serious concerns about the adequacy of its existing water supply capability. As a result, the Province of Manitoba requested PFRA's assistance in investigating measures for making more efficient use for water supply purposes of storage already available in the Shellmouth Reservoir, and thereby increasing the assured water supplies which can be obtained from it. This report documents the results of those investigations.

### Study Methodology

The study was a joint federal-provincial initiative carried out by staff from PFRA and Manitoba Water Resources. Under the guidance of a Steering Committee, each agency carried out established portions of the work. Results were reviewed by both federal and provincial officials, and conclusions and recommendations were jointly agreed to.

The methodology followed in carrying out this study was as follows:

- Existing and anticipated future water demands (including municipal, industrial, on-farm and irrigation) along the entire length of the Assiniboine River below the dam were determined;
- A computer model was developed for simulating how these water demands could be met through local inflows supplemented by releases from the Shellmouth Reservoir;
- A number of scenarios (covering the range of realistic physical possibilities) for changing the reservoir's operating regime were identified and analyzed in a preliminary fashion with regard to increased water supply capability, loss of flood damage reduction capability, and expected environmental impacts;
- Based on the above analysis, a number of originally identified scenarios were deleted from further consideration at this time; and only two, one including installation of spillway gates, were retained for detailed evaluation;
- These two scenarios were studied in detail including water supply simulations; preliminary design and costing of spillway gates; and assessments of impacts on fish, wildlife, reservoir development, lands upstream of the reservoir, etc.
- Study results were compiled and documented in this report.

# Historical Perspective

## General

After the disastrous flood of 1950, various physical measures for reducing flooding on the Red and Assiniboine Rivers were investigated. These studies indicated that "the most feasible plan for relieving flood threat and ensuring a sufficient water supply to meet foreseeable water demands along the river (Assiniboine) would be a combination of a dam at Shellmouth and the diversion of the river into Lake Manitoba near Portage la Prairie"<sup>1</sup>. These two projects were ultimately implemented on a 50-50 cost share basis by the governments of Canada and Manitoba. In combination with a federally maintained dyking system east of Portage la Prairie, they have greatly reduced historic flooding problems along the Assiniboine River, and the Shellmouth Reservoir has significantly augmented flows during natural low-flow periods.

The Shellmouth Dam was designed and built by PFRA. Construction was started in 1965 and completed in 1969 at a cost of \$10.8 million. The dam, located about 20 km northwest of Russell, has a maximum height of 22 m, a crest length of 1 270 m, a 4.6 m diameter reinforced concrete conduit for making releases from the reservoir, and an ungated concrete chute spillway designed to pass the thousand year flood. The reservoir created by the dam extends approximately 60 km upstream, and is capable of storing 477 000 dam<sup>3</sup> of water at spillway crest elevation.

## Current Reservoir Operating Regime

Although originally intended primarily for flood reduction and water supply purposes, the reservoir was found capable of supporting a variety of other uses. The most important of these are fisheries and recreation.

In order to accommodate these varied uses, which are often conflicting in terms of desired reservoir operations, Manitoba Water Resources has developed, and follows to the extent possible, the following annual operating regime:

- During the winter, the reservoir is lowered to approximately 424 m elevation to provide storage for spring floods and hence provide downstream flood reduction;
- During spring runoff, outflows are controlled to minimize downstream flooding. Excess inflows are stored in the reservoir until the water level reaches the crest of the uncontrolled spillway at elevation 429.3 m;

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<sup>1</sup> Federal Treasury Board Minute 586732, June 15, 1962

- After spring runoff, reservoir levels are gradually lowered by conduit releases to elevation 427.5 m. This level is then maintained (subject to downstream water requirements) as much as is possible for recreation and fisheries purposes;
- In the event of summer rainfall floods, the storage available between elevation 427.5 m and the spillway crest is used to reduce downstream flow rates;
- Throughout this operating sequence, sufficient water is released from the reservoir to meet downstream consumptive and instream needs.

It should be noted that the winter drawdown target is somewhat variable. As Manitoba Water Resources gained experience in operating the reservoir, winter drawdowns were, and are, adjusted on the basis of probability forecasts of spring inflow. This operation has increased the reservoir's water supply capability while maintaining its flood damage reduction capability. In effect, introduction of the probability forecasting has caused current operation to migrate in the direction of the operating adjustments examined in this study.

The current operating regime, and how it relates to the physical features of the Shellmouth Dam, is shown schematically on Figure 2. While not to scale, the figure also shows features such as top of dam, elevation of the spillway crest, the invert of the conduit, and the riverbed just above the dam. Also shown are operating target levels, the reservoir's effective empty level (in terms of the conduit's hydraulic capacity, with allowance for an ice-cover approximately 1 m thick), and historically recorded maximum and minimum water levels.

### **Changes Caused by the Reservoir**

#### **Reservoir Levels**

Records of water levels in the reservoir have been collected on a continuous basis since it started filling in 1969. Shown in Figure 3, these illustrate graphically the above-described operating regime. As can be seen, since 1971, when the reservoir came into full operation, reservoir levels have exceeded the spillway crest six times, with the maximum recorded water level being 430.225 m. In terms of low water levels, the recorded minimum of 422.737 m occurred as a result of the reservoir being lowered in preparation for a large inflow in the spring of 1979. Therefore, even with the droughts of the 1980s, the reservoir has never been stressed with regard to its water supply capability (i.e. the reservoir's effective empty level of 419.7 m has never been approached).

### **Downstream Flows**

In keeping with its objectives of providing both flood reduction and water supply benefits, the reservoir has significantly changed the flow regime of the Assiniboine River. Relative to natural conditions, flood peaks have been greatly reduced, while during dry periods flows have been much larger than they would have been. This is illustrated in Tables 1 and 2. These show, for the years since the reservoir was created, the annual maximum and minimum daily flows recorded at Brandon and Portage la Prairie. Also shown are what the flows would have been without the reservoir. These data indicate that flood peaks have generally been reduced, with the amount depending on the nature and timing of floods. Conversely, flows which would have dropped to or near zero at Brandon in four years were maintained at considerably higher levels.

This augmentation of low flows is further illustrated for Brandon and Portage la Prairie in Figures 4 and 5, respectively. They show the flows recorded during the drought years of 1988 and 1989, as well as the flows that would have occurred without the Shellmouth Reservoir. A quantitative assessment of how much the reservoir has augmented the water supply capability of the Assiniboine River is presented in Chapter 4 of this report.

### **Recreation and Fisheries**

Since its creation, the Shellmouth Reservoir has developed into a significant recreation and fisheries resource. Its relatively stable summer water levels and large surface area allow considerable water-based recreation including swimming, boating and fishing. These pursuits are supported by the Assiniboine Provincial Park which is located just upstream of the dam, and by numerous private campgrounds and boat launch areas.

The reservoir also greatly enhances the fishery resource on the entire Assiniboine River. The reservoir itself has, with an annual stocking program by Manitoba Natural Resources, evolved into one of the province's most prized fishing areas. In addition, the already noted flow augmentation has enhanced fish habitat and fishing opportunities along the entire river.

### **Public Concerns**

In carrying out this study, a number of informal meetings were held with residents and local elected officials from areas that could potentially be impacted by changes to the reservoir's operating regime. These included the rural municipalities of Russell, Shellmouth, Shell River, and Cote (Saskatchewan), and the towns of Russell, Roblin, and Kamsack (Saskatchewan). While no formal records of these meetings were kept, the concerns expressed are summarized below.



People located above the reservoir, i.e. in the Kamsack area of Saskatchewan, indicated a belief that the reservoir has negatively impacted drainage of low-lying agricultural land to the southeast of Kamsack. While the issue has been addressed a number of times, it has never been resolved; and residents have not received financial compensation they feel entitled to.

Officials from the municipalities in which the reservoir is located were concerned about historic and potential loss of municipal tax revenues caused by loss of agricultural land to the reservoir; while residents below the dam felt that they have been negatively impacted by longer durations of at or near bankfull flows after passage of spring peaks.

In addition to the above, inputs were also received from people along the river, primarily in the Portage la Prairie area, concerning the adequacy of existing water supplies from the river. These concerns were in large part based on perceived water shortages during 1988-89, or on difficulties in pumping or removing water from the river.

Not all the above concerns fell within the scope of this study. They were, however, addressed to the extent possible, and are documented as appropriate later in the report.

# Reservoir Operating Alternatives

## General

The Shellmouth Reservoir's assured water supply capability is directly related to the extent to which the reservoir is lowered each winter in preparation for possible spring floods. This is because there are no guarantees that spring runoff will be sufficient to refill the reservoir to desired levels. Hence, only that volume of water still in storage after the winter drawdown can be counted on for water supply purposes. Therefore, the most effective way of increasing the water supply capability of the existing reservoir would be to reduce the extent to which the reservoir is drawdown each winter.

This adjusting of the winter drawdown can be considered in terms of the existing summer water levels as well as other operating regimes which might have higher or lower summer water levels. This, plus the question of just how far the reservoir should be lowered, presents an infinite number of reservoir operating possibilities which could be considered.

## Identification of Alternatives

One of the first tasks undertaken in the study was the identification of a workable number of reservoir operating alternatives. This was done through a series of consultations with senior technical staff from PFRA and experienced water managers from Manitoba Water Resources.

A total of four alternatives, referred to as Modified Base, Gated 1, Gated 2, and Gated 3 scenarios were identified. They were defined so as to cover the full range of reservoir operating alternatives which could realistically be considered. Details of each are as follows:

- Modified Base was derived from the existing operating regime in that the only parameter which was changed was the winter drawdown level. This was set at elevation 426.7 m rather than 424.0 m. This was considered adequate to provide a substantial increase in water supply capability while still maintaining a reasonable flood reduction capability;
- Gated 1 would have the same drawdown regime, and hence the same increase in water supply capability, as Modified Base. The difference would be the installation of gates on the currently ungated spillway. It was anticipated that these would enable the retention of a significant portion of the flood reduction benefits that would be lost for the Modified Base scenario;

- Gated 2 assumed a raising of the summer water level to elevation 429.3 m (the same elevation as the spillway crest), and setting the winter drawdown level at 426.7 m. This was considered likely to provide a slightly larger water supply capability than Modified Base or Gated 1. The scenario included installation of spillway gates as the chief means of obtaining flood reduction capability;
- Gated 3 is similar to Gated 2 in that it would entail raising the summer water level to elevation 429.3 m. The winter drawdown would, however, only be to elevation 427.5 m (the current summer level), hence affording an increase in water supply capability relative to Gated 2. Flood reduction capability would again be obtained through installation of spillway gates.

### **Preliminary Screening**

After the four scenarios were identified, they were evaluated in preliminary fashion to determine if they merited detailed examination. The evaluations were carried out in terms of: increased water supply capability; peak reservoir water levels and outflows (for a variety of spring floods); and potential impacts on fish, wildlife, parks, recreation, reservoir area, and flooding. The water supply evaluations were carried out by Manitoba Water Resources using a simplified simulation program; PFRA developed a series of theoretical flood hydrographs and routed them through the reservoir in strict accordance with existing operating rules; and the study team, with input from various branches of Manitoba Natural Resources, assessed impacts on related resources. PFRA also carried out a review of available data and literature on the impacts of reservoir flooding on mercury levels in fish.

Once the above analysis were complete, the results were tabulated and evaluated by the study team. The scenarios were compared, for each of the above parameters, to the existing reservoir operating regime and to one another. In some cases, the evaluations were quantitative, in others only qualitative or relative. This evaluation indicated that:

- Modified Base would increase water supply capability significantly relative to existing conditions; would negatively impact on downstream flood flows; would cause little increase in flooded area; and would be relatively neutral for fisheries, wildlife, and parks interests;
- Gated 1 would have the same water supply increase as Modified Base; would be relatively neutral on downstream flows for small floods but negatively impact on downstream flows for large floods; would cause considerable flooded area concerns both in Manitoba and Saskatchewan; and would be relatively neutral for fisheries, wildlife, and parks interests;



- Gated 2 would provide approximately 40% more water supply capability than Modified Base; would have the same impacts on downstream flood flows as Gated 1; would cause considerable flooded area concerns; would likely necessitate purchase of additional land and reservoir clearing; would have negative impacts on fisheries, parks, and recreation interests; and would be neutral regarding wildlife;
- Gated 3 would provide approximately 80% more water supply capability than Modified Base; would slightly worsen impacts on downstream flood flows relative to Gated 1 and Gated 2; would increase flooded area, land purchase, and reservoir clearing concerns relative to Gated 2; would have negative impacts on fisheries, parks, and recreation interests; and would be neutral regarding wildlife.

### Scenario Selection

From the preliminary screening, it was concluded that the Modified Base and Gated 1 scenarios were the only ones that should be studied in greater detail at this time. It was felt that they offered sufficiently large water supply increases to merit consideration, while environmental costs and loss of flood damage reduction capability were anticipated to be limited and localized.

Further consideration of scenarios Gated 2 and Gated 3 was deferred for the time being. While offering larger water supply increases than Modified Base and Gated 1, it was felt that their potential environmental impacts could be significant and more difficult to mitigate. Of particular concern was the question of whether or not, or to what extent, increases in reservoir flooded area would impact on mercury concentrations in fish. Given their increased summer flooded areas, this concern was most pronounced for Gated 2 and Gated 3.

Once the above screening and selection process was complete, Modified Base and Gated 1 were recommended for further study. This recommendation was accepted by senior officials of PFRA and Manitoba Water Resources. These scenarios including Base (existing) were subsequently modified to include probability forecasting with flexibility to vary the winter drawdown to the minimum target level to reflect existing operation (Appendix I). More detailed evaluations were then carried out.



# Water Supply Simulations

## General

The water supply implications of the selected operating regimes were investigated through a series of detailed water supply/demand simulations of the main stem of the Assiniboine River system. The work was carried out by Manitoba Water Resources and entailed: compiling a listing of all existing water usage from the Assiniboine River between the Shellmouth Dam and the City of Winnipeg; estimating future (in terms of a 50 year horizon) levels of usage from the Assiniboine River; developing and calibrating a computer-based hydrologic/hydraulic model of the system; developing a sufficiently long data base of river flows, local inflows, and weather conditions for use in the simulation model; and running the simulation model to determine the water supply capability of the Shellmouth Reservoir, and the impacts of each operating scenario in terms of reservoir water levels, flooded areas, and reservoir discharges.

## Water Demands

Existing (as per 1990) water usage from the Assiniboine River was calculated by reviewing all existing water rights licenses which permit withdrawals from the river, and summing them. These data were tabulated for three reaches of the river: Shellmouth Reservoir to Brandon; Brandon to Portage la Prairie; and Portage la Prairie to Winnipeg. The results are summarized in Tables 3, 4, and 5. They indicate current annual licensed withdrawals from the Assiniboine River as a whole of 64 000 dam<sup>3</sup>; composed of 27 300 for irrigation, 9 700 for municipal and industrial purposes, and 27 000 for use in the La Salle River watershed (for irrigation, on-farm, and municipal purposes).

It should be noted that these usage levels were not based on an actual monitoring of withdrawals from the river. They may, therefore, be on the high side because not all licenses are necessarily being used, or used to the maximum amount of the license. This possibility is supported by a recent survey of Manitoba irrigators by Gaia Consulting. Their work indicates that 1991 irrigation withdrawals from the Assiniboine River were in the order of only 7 000 dam<sup>3</sup>.

Future water demands were estimated by projecting historic licensed water use rates, and adding to them known potential uses. The time horizon used was 50 years. Also shown in Tables 3, 4 and 5, these estimates indicate an approximate doubling of annual water demands to 117 000 dam<sup>3</sup>; composed of 54 000 for irrigation, 18 000 for municipal and industrial purposes, 27 000 for the La Salle River watershed, and 18 000 for the Pembina Valley Water Co-op should the proposed 0.57 m<sup>3</sup>/s diversion to the Pembina Valley (for which a water supply reservation is in effect) be implemented.

## Water Supply Analysis

In order to investigate the water supply capability of the Shellmouth Reservoir, Manitoba Water Resources developed a computer-based model capable of simulating the hydrologic and hydraulic regime of the main stem of the Assiniboine River. It included a reservoir routing component for determining outflows from and water levels on the Shellmouth Reservoir.

This model, more fully documented in Appendix I, was run for a 78-year hydrologic record based on weather and streamflow data for the period 1913 to 1990. It considered inflows to the Shellmouth Reservoir as well as local inflows and tributary inflows to the Assiniboine River below the dam. Where possible, natural flows based on recorded data were used to develop these flow arrays. Where recorded data was not available, data was appropriately transferred from other locations or developed through regression analysis with other data sources.

The model was designed to calculate, for downstream inflow conditions, releases that would have to be made from the Shellmouth Reservoir to meet specified water demands. In addition, the model was required to maintain minimum flows of 5.66 m<sup>3</sup>/s at Brandon for cooling purposes at Manitoba Hydro's generating station\* and 2.83 m<sup>3</sup>/s for instream purposes at Headingley. The resultant reservoir outflow array was then coupled with reservoir inflows and precipitation and evaporation data to calculate reservoir water levels. If the reservoir did not fall below the effective empty level of 419.7 m, it was considered capable of providing, on an assured basis, the specified consumptive water demands.

The water supply analysis was carried out for the selected scenarios and for current operating rules in terms of both current and future water demands. The results are summarized in Table 6.

They indicate that as currently operated, and with the minimum flow constraints for Brandon and Headingley, the Shellmouth Reservoir is capable of assuring 132 000 dam<sup>3</sup> for water supply purposes along the Assiniboine River. This is well in excess of current demands and slightly more than the estimated future demands.

This finding is inconsistent with concerns expressed by residents along the river, particularly in the Portage la Prairie area, that the river is already over-taxed and incapable of meeting even current demands. These concerns, based largely on flow conditions during 1988 and 1989, were determined to be unfounded. A review of operating decisions made during this period revealed that Manitoba Hydro did not need to operate its Brandon generating station during the low flow periods and as a result, Manitoba Water Resources set a flow target of 2.8 m<sup>3</sup>/s for Brandon. As shown

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\* This minimum flow is required only when the generating station is operated. The constraint was however applied continuously in the simulations because there was no way of determining when, during the period of record, the station would not have been used. It was recognized that this was conservative and likely wasted water.

in Figure 4, this target was not met for a short period of time from July 27 to August 11, 1989. This, however, was not due to a shortage of water in the reservoir, which at that time was at elevation 426.6 m. Rather, it was due to operational difficulties concerning timing of releases from the reservoir and arrival of that water in Brandon. Table 2 and Figure 5 show that flows at Portage la Prairie were never less than  $4.0 \text{ m}^3/\text{s}$  during 1988 and 1989. Water Survey of Canada records indicate that the minimum flow at Headingley over this period was  $2.86 \text{ m}^3/\text{s}$  on August 14, 1989, sufficient to meet instream flow needs.

Other problems which were noted, such as difficulties with pump intakes, were felt to be at least in part attributable to the meandering nature of the river causing shifting sand bars to obstruct intakes. While more pronounced at low flows, these types of problems could occur at any time.

The simulations for the more water-supply oriented Modified Base and Gated 1 operating regimes indicate that the Assiniboine River's water supply capability would be increased by  $12\,000 \text{ dam}^3$ , a gain of approximately 9%. This increase is somewhat less than originally anticipated because the probability forecasting included in the current operating mode has already caused a shift toward Modified Base or Gated 1, hence reducing the incremental water supply increases that could be attributed to them.

It should be noted that while the reservoir was considered effectively empty for water supply purposes at elevation 419.7 m, it would still hold approximately  $68\,000 \text{ dam}^3$ , and have a maximum water depth of roughly 5 m. Minimum reservoir levels that would have been reached under the demand and operating regimes which were analyzed are shown on Figure 6.

## **Other Considerations**

### **General**

In the course of this study, a number of factors which could potentially impact on water supply conditions along the Assiniboine River were raised. The most significant were: a) Saskatchewan retaining for consumptive use its share of the Upper Assiniboine's runoff originating in Saskatchewan; and b) a possible reduction in the minimum flow requirement of  $5.66 \text{ m}^3/\text{s}$  at Brandon.

The above factors may or may not affect the future water supply along the Assiniboine River. They were, therefore, examined only in a sensitivity analysis fashion with regard to their impacts from a water supply perspective. Their impacts on flood flows, reservoir levels, etc. were not examined.



## **Saskatchewan Flow Apportionment**

According to the Master Agreement on Apportionment administered by the Prairie Province's Water Board, Saskatchewan is legally entitled to use one half of the Assiniboine River's natural flows originating in Saskatchewan. Were Saskatchewan to do so, through the construction of reservoir storage or diversion works, the Shellmouth Reservoir inflow array developed for this study would be reduced. To obtain an indication of whether or not this would have a significant impact on the reservoir's water supply capability, the water supply simulations were re-run assuming approximately 140 000 dam<sup>3</sup> of storage in the Saskatchewan portion of the basin. This volume was obtained from a review of previously examined water supply options for this area in which nine potential dam sites were identified. The indicated volume is the total storage for all nine sites and was assumed to represent an upper limit of what could physically (although it was felt to be realistically very unlikely) be developed. For purposes of the analysis, it was assumed that Saskatchewan withheld 50% of annual natural runoff up to a maximum of 140 000 dam<sup>3</sup>. All excess flows were assumed to enter the Shellmouth Reservoir.

This analysis indicated that with the above apportionment, and for current consumptive demands and assumed minimum flow requirements at Brandon and Headingley, the Shellmouth Reservoir would fall to about 1 m below the effective empty elevation of 419.7 m for both the Base and Modified Base operating modes. While in the strictest sense of the definition this would not be considered as assuring demand conditions are met, it is likely that the reservoir could successfully be lowered to the indicated elevation, particularly during drought periods when adverse conditions are anticipated.

## **Reduction of Minimum Flow at Brandon**

As noted earlier, a minimum flow of 5.66 m<sup>3</sup>/s is currently required at Brandon for cooling purposes when the thermal generating station is in operation. Manitoba Hydro now anticipates that after 1996 there will be a cooling tower sufficiently large to meet all cooling requirements at the Brandon Station. Under these conditions Manitoba Hydro's maximum water withdrawals will be 0.7 m<sup>3</sup>/s, with no minimum downstream flow requirement.

To analyze this possibility, consumptive demands at Brandon were increased by 0.7 m<sup>3</sup>/s and the minimum downstream flow requirement was reduced to 2.83 m<sup>3</sup>/s. This is consistent with the minimum flow constraint for instream purposes at Headingley.

With these assumptions and current operating rules the analysis indicated the reservoir would not drop below the recorded minimum level of 422.7 m, even for future demands. Incorporation of Saskatchewan apportionment would, for future demands, result in a minimum reservoir level of 421.9 m. Under Modified Base and Gated 1 the minimum reservoir level would be 423.6 m.



# Impacts

## General

Changing the Shellmouth Reservoir's operating regime to focus more on water supply cannot be accomplished without incurring some trade-offs in terms of other reservoir uses. The study, therefore, included the identification and evaluation of those impacts which the operating scenarios under investigation would lead to. Included in this evaluation, where possible, was the identification and appraisal of mitigative measures.

Impacts were divided into two categories: a) hydrologic or water regime changes which would be caused by altering the reservoir's method of operation; and b) the environmental impacts which would result from the hydrologic changes.

As noted earlier, this work was only carried out for the Modified Base and Gated 1 scenarios; was based on the originally developed historic inflow array; and considered only the estimated current and future water demands, including the minimum flow requirements of  $5.66 \text{ m}^3/\text{s}$  and  $2.83 \text{ m}^3/\text{s}$  at Brandon and Headingley, respectively.

Also included and identified as Base are results obtained by simulating operation under current operating rules.

## Hydrological Impacts

### General

The hydrologic or flow regime aspects which were examined are the flow regime immediately downstream of the Shellmouth Dam, flood peaks at Miniota, Brandon and Portage la Prairie, reservoir water levels, and upstream backwater effects in the Kamsack area of Saskatchewan. These were felt to realistically cover the range of hydrological aspects and their area of applicability which the operating changes might impact.

Having been carried out on a daily basis, the analysis generated a large volume of data. For clarity and presentation purposes, this data was to the extent possible summarized in tabular or figure form. In some cases, it was aggregated to monthly averages or averages over the period of analysis.

## **Flow Regime Below The Dam**

Since creation of the Shellmouth Reservoir there have essentially been no flooding problems in the reach of river immediately below the dam. The water supply simulations therefore included the calculation, for the scenarios under consideration, of releases or spillway flows from the reservoir. The output from this work was analyzed and summarized in tabular form.

Table 7 shows the maximum daily outflow which would have occurred in those years when downstream channel capacity (approximately  $43 \text{ m}^3/\text{s}$ ) was exceeded. As can be seen, relative to current rules (i.e. Base), increases up to 86% could be expected under Modified Base. The addition of spillway gates would in most low and moderate flow years considerably reduce the magnitude of these increases. During extremely high flows, however, the addition of gates would have little impact. These outflow increases would not be significant at downstream locations such as Miniota and Brandon where peak flows would be considerably higher than those below the reservoir.

Maximum annual outflows are also shown on Figure 7, where Modified Base and Gated 1 results are plotted against corresponding Base values. Points above the solid line indicate an increase in outflow rate relative to Base, while points below the line indicate a decrease.

In addition to the floods analyzed in the water supply simulations, a number of theoretical spring and summer floods, i.e. the 1:100, 1:500, and 1:1000 events, were also routed through the reservoir. This work, summarized in Table 8, indicates that the proposed operating changes would have little impact on either spring or summer floods of these magnitudes. This is because the volumes of water in these floods are so much larger than what could be stored in the reservoir that the changes in reservoir operating regime become of little significance in terms of reducing peak river flows.

An indication of how the flow regime would change in a longer term context is shown in Table 9. Daily outflows for current demands were first averaged by month for each year, and then by month for the period 1913 to 1990. This indicates that winter flows would generally be lower for both Modified Base and Gated 1; spring flows would be somewhat higher; and summer flows would be very similar to existing. Because of the averaging, results for future demands were not significantly different and hence are not shown.

## **Downstream Flood Flows**

As part of this study, the model was modified to allow calculation of daily flow rates, including flood peaks, at Miniota, Brandon, and Portage la Prairie. The previously developed outflow hydrographs for the 1913 to 1990 period of record were routed to these downstream locations and combined with local inflows. The results are shown on Figures 8, 9, and 10.

To provide additional detail, those years for which flows would have exceeded bankfull capacity were identified, and the results of each scenario were compared to existing conditions. This work is summarized in Tables 10, 11, and 12. As can be seen, the results are very random both by year and location. This is likely due to the differences from year to year in the timing of peak flows from local inflow and on major tributaries. Very general observations that can be made are that downstream flood peaks would be generally somewhat higher under Modified Base than is currently the case. Installation of spillway gates would, on average, roughly reduce these increases by half.

### **Reservoir Levels**

The water supply simulations also included calculation of daily reservoir levels for existing conditions and for the two scenarios under consideration. It should be noted that the existing operating regime, which emphasizes flood damage reduction benefits, includes a physical and probability based reservoir inflow forecasting component. This allows provincial water managers some flexibility in terms of how far the reservoir is lowered each winter (i.e. the March 31 water level may be somewhat higher or lower than elevation 424 m depending on inflow forecasts). For the Modified Base and Gated 1 scenarios, which are intended to shift focus more to water supply, the maximum winter drawdown to elevation 426.7 m was adhered to in the simulations.

The results of the daily simulations are shown on Figures 11 and 12 for current and future demands, respectively. These clearly demonstrate that the reservoir would be most severely stressed during the period 1937 to 1942, the most severe drought on record. The figures also show that winter water levels would be higher and more constant under Modified Base and Gated 1 than is currently the case. This is simply a reflection of how the proposed scenarios were defined in terms of reducing the extent of winter drawdowns. During open water months, reservoir levels for Modified Base and Gated 1 would generally be higher, with changes most pronounced during April, May, and June. These results are further illustrated in Table 13, wherein mean monthly reservoir levels (based on the entire period of record), are summarized for each scenario.

Figures 11 and 12 also show that installation of spillway gates would result in significantly higher reservoir levels for many flood events. This is also in accordance with the basic scenario definition, in that gates would be used to provide storage foregone by not lowering the reservoir as much over winter or by holding back more of summer floods than is currently possible. This information is also illustrated on Figures 13 and 14, wherein water level data is shown in terms daily maximums, minimums, and averages (as determined from the entire period of record). It is of interest to note that comparison of annual minimums for current demands and future demands indicates that minimums that could occur under current demands could be maintained under future demands if the reservoir operating mode were changed to

either Modified Base or Gated 1.

### **Reservoir Backwater Effects**

Included in the Shellmouth Dam project was purchase of the land that would be inundated by the reservoir or perceived to be potentially impacted by backwater effects of the reservoir. This land purchase extended up the Assiniboine Valley from the dam to approximately eight km southeast of Kamsack, Saskatchewan. No impacts were originally anticipated upstream of this point. Subsequent investigations have however indicated that this may not be the case.

This study included an attempt to determine if and to what extent the Modified Base and Gated 1 scenarios would create backwater effects over and above those currently being experienced during the agricultural growing season. To do this, water levels which would have occurred near Kamsack with the reservoir in place were calculated for the period during which flow records are available at Kamsack (1944 to 1990).

The results of these computations, in terms of maximum annual water levels after May 1st, are summarized in Table 14 for flood years. This analysis indicates that relative to existing conditions, increased backwater effects would have occurred eight times under Modified Base and Gated 1. The magnitudes of these changes would, however, be relatively small.

### **Environmental Impacts**

#### **General**

The study included a very preliminary scoping of environmental impacts which might be caused by the previously discussed hydrologic or water regime changes. This work, largely done by PFRA staff, incorporated issues or concerns raised by Manitoba Natural Resources officials who provided input to the preliminary screening of scenarios.

Impacts or impact areas which were identified are: the reservoir; fisheries; mercury concentrations in fish; recreation and transportation facilities; and land drainage near Kamsack. Each is addressed in more detail in the following sections.

#### **Reservoir Impacts**

A preliminary scoping of environmental issues pertaining to the reservoir was carried out. From this, it was concluded that the most significant impacts would result from limiting the winter drawdown to elevation 426.7 m, rather than the normal 424.0 m, thus reducing the physical size of the drawdown zone (that area, generally devoid of vegetation due to its being inundated during the growing season, exposed by the annual lowering of reservoir water levels), and from the generally higher and more

prolonged spring peak water levels. These factors could potentially lead to the following environmental impacts:

- an increase in available stable habitat for many forms of aquatic life due to an increase in the area covered by water year round;
- increases in emergent and submergent aquatic plants with a concurrent increase in secure fish spawning sites. Such permanent aquatic vegetation could offer more protection from predators and a more dependable food supply, possibly resulting in increased growth and increased numbers of fish. The reservoir's fish species composition could, however, be changed due to changes in breeding and rearing habitat;
- changes to water temperatures in the reservoir. This could impact plant and animal species both in the reservoir and downstream;
- dissolved oxygen levels could be reduced at lower depths due to increased water depths. This could increase the concentrations of certain toxic chemicals such as manganous and sulfide ions;
- long-term sediment production, and hence turbidity, could be reduced due to more stable water levels. This could be somewhat offset by higher spring levels, particularly for Gated 1;
- nutrient loadings could be increased by higher and more prolonged spring water levels, particularly for Gated 1;
- mercury concentrations in fish could be increased because of the larger area inundated during winter and spring;
- scour due to wave and ice action could be increased in the short term due to the exposure of new shore-line areas to relatively constant water levels, and due to higher and more frequent peak water levels, particularly for Gated 1;
- significant increases in the amount of ice formed due to increased surface area at freeze-up. If carried over the spillway, this could create negative impacts downstream.

### **Fisheries**

As already noted, the scenarios under consideration could affect mercury concentrations in fish. This will be discussed in more detail later.

From the preliminary scoping of potential impacts on fish, it was concluded that:

- Modified Base would not likely cause significant negative impacts. This is because the reservoir's non-winter water level regime would be largely unchanged; and the higher winter water levels would likely be beneficial. Downstream, the reservoir's increased water supply capability could lead



to increased river flows during dry periods, thereby enhancing aquatic environments along the river.

- Gated 1 could cause significant negative impacts on fish in the reservoir. Higher and more prolonged spring water levels could impact on traditional spawning areas; and could cause higher nutrient loadings which would likely increase production of algal blooms and hence fish kills when the blooms decay. These negative impacts could be somewhat mitigated by the beneficial effects of higher winter water levels. The downstream impacts would be similar to those for Modified Base.

### **Mercury Concentrations in Fish**

As indicated in the discussion on scenario definition, one of the major environmental concerns encountered during this study was if, and to what extent, mercury concentrations in fish would be affected by changes in the reservoir's operating regime. Given the significant and important sport fishery which has developed on the Shellmouth Reservoir over the last 20 years, a concerted attempt was made to obtain an understanding of this issue. To that end, an extensive literature review was conducted, and federal and provincial government experts on fish and water quality were consulted.

This work indicated that:

- while creation of reservoirs has in general often been inferred as a cause of elevated fish mercury concentrations, knowledge of the source of mercury in fish is still incomplete. However, much of the up-to-date research seems to confirm empirically that post-impoundment mercury levels in predatory fish are related to the flooded terrestrial area compared with pre-impoundment lake areas. Unfortunately, there are no models or empirical data to accurately predict the relationships between the percentage of land flooded and resultant increases in methyl mercury in fish;
- at present, methyl mercury levels for walleye in the Shellmouth Reservoir average greater than 1.0 ppm with some samples being in excess of 2.0 ppm. Downstream at Brandon, walleye average less than 0.5 ppm, the current limit (set by Health and Welfare Canada) for methyl mercury in fish sold for human consumption;
- it is not possible from available data of mercury in fish or the general understanding of the mercury problem in reservoirs to predict quantitatively the expected increases in mercury concentrations or to predict when concentrations might decrease to pre-impoundment levels;
- mercury impacts may be reduced or mitigated through the removal of



vegetation and organic matter, and by minimizing shoreline erosion which adds suspended sediments to the water body.

### **Recreation and Transportation Facilities**

In order to determine the potential impacts on existing recreation and transportation facilities located around or over the reservoir, PFRA carried out a shoreline evaluation. It included interpretation and inspection of various types of maps (NTS sheets, Manitoba Parks Branch drawings, and Manitoba Department of Community Development Land Use Plans), and a visual inspection of both shores by boat.

This evaluation indicated that while the reservoir is used extensively by boaters, fishermen, campers and cottagers, there are very few man-made immovable structures within 6 to 9 m of the summer target water level of 427.5 m. It revealed that there are 4-5 seasonal trailers, one boathouse and one fixed dock situated at levels less than 2.5 m above the target summer water level. All other facilities, i.e. floating docks, boat launches, camper trailers, etc. are removable or well above summer water levels.

It was also concluded that management of Assensippi Provincial Park would not be severely impacted, other than that adjustments would have to be made to accommodate higher ice levels in winter and lengthier periods of spring flooding.

The elevations of the undersides of the stringers in the centers of bridges on Highway 5 and Highway 369 (Saskatchewan) were also determined. They were found to be 431.8 m and 432 m, respectively. As shown by the reservoir water level hydrographs, this is well above normal high water levels, except for very large floods. Whether or not these bridges would be affected structurally by Modified Base or Gated 1 was not addressed. This will have to be further studied should changes to the reservoir's operating regime be adopted.

### **Land Drainage Near Kamsack**

Since completion of the Shellmouth Dam in 1969, there have been complaints that land lying along the floor of the river valley upstream of the reservoir takeline (i.e. line to which land had been purchased for the reservoir) has been unfavourably affected by the water levels in the reservoir. The most common complaint has been that land that is flooded by the river during natural spring floods is flooded for a longer period of time, is slower to drain, and is slower to dry; resulting in reduced seeding opportunity, often such that it is not possible to raise a frost-free wheat crop, necessitating planting of a shorter growing season crop.

These concerns have been investigated a number of times in the past. A precise definition of the nature of the problem and the financial losses it may have historically caused was, however, never arrived at. The most recent investigation was by PFRA in 1986. The impact assessment methodology used in this study was empirical in nature.

and utilized simulated hydrographs prepared assuming the pre mid-1980s reservoir operating regime (which has since been changed to include a forecasting component). This work was never subjected to rigorous technical review, and was never finalized.

However, in the absence of a detailed analytical study relating reservoir backwater effects and water-table levels beneath the adjacent cultivated lands, for this study it was decided to use the 1986 empirical impact assessment methodology to obtain an indication, **with no presumption as to the validity of the absolute numbers**, of how and to what extent the operating scenarios under consideration would impact on backwater and drainage conditions near Kamsack.

The basic assumptions used in the 1986 empirical assessment were that: after passage of a flood, water levels in the river have to drop a certain amount before nearby low-lying fields will drain; impacts on seeding would only be considered after May 1; seeding has to be complete by June 1 in order to produce a frost-free crop; and a minimum of 10 days is necessary for seeding operations.

Through an analysis relating river flows at Kamsack, Shellmouth Reservoir water levels, and reservoir backwater relationships, estimates were made of the number of years in which the existence of the reservoir may have reduced seeding opportunity to 10 days or less. The work indicated that lands as high as elevation 432.8 could, albeit very rarely, be subject to delayed seeding. The maximum area that would be affected was estimated to be 783.4 ha.

For this study, potential land impacts under the two alternative operating regimes were considered at only one location, that being immediately above the reservoir takeline (the 1986 study also considered a location slightly further upstream). The results of this work, expressed in terms of seeding opportunity and lost seeding opportunity is shown in Table 15. It indicates, for the location considered, that relative to existing conditions seeding opportunity would have been reduced about 11 times (with the reduction being to 10 days or less once in those years) under Modified Base. Under Gated 1, reductions may have occurred in about 12 years, with the reductions to less than 10 days occurring in about four of those years.

It must be stressed that the above numbers are for indication purposes only. Detailed analytical studies relating reservoir backwater effects and the water-table levels beneath adjacent cultivated lands **are still required to confirm** both the validity of the 1986 empirical impact assessment methodology and the technical propriety of using this methodology to estimate impacts under the alternative operating regimes under consideration.

# Spillway Gates

## General

As demonstrated by the reservoir routings of historic floods, changing the reservoir's operating regime to Modified Base would result in some loss of downstream flood protection benefits. Some of these could be recovered (or never lost); and summer flood protection benefits could be increased through the installation of gates on the dam's currently ungated spillway.

PFRA's Design Division investigated the feasibility of modifying the existing spillway structure to incorporate control gates. Four gate types: radial, vertical lift, rubber dams, and drop leaf, were considered. Each option was investigated at a preliminary level, and a cost estimate prepared. Details of these investigations are provided in Appendix II.

The preliminary investigations included assessments of both the structural and hydraulic feasibility of each option. The preliminary structural analysis of the gates entailed the sizing of the primary horizontal and vertical members and the skin plate for a loading condition where the gates were assumed closed and the reservoir at top of dam. The resultant gate weight was calculated and used to verify the approximate gate weight provided by suppliers who quoted both estimated gate weights and costs. Hydraulic analysis were based on the characteristics of individual gate types, and their effects on the discharge characteristics of the existing uncontrolled ogee spillway crest.

Each option was then analyzed, including determination of relative advantages and disadvantages. Costs were estimated and found to range from \$910,000 to \$1,950,000.



## Conclusions And Recommendations

### Conclusions

Based on the investigations carried out in the course of this study, it was concluded that:

- Creation of the Shellmouth Reservoir has greatly changed the flow characteristics of the Assiniboine River in Manitoba. Flood flows have been reduced to the point where flooding is no longer a major problem along the river. Conversely, low flows have been augmented such that minimum flows of  $5.66 \text{ m}^3/\text{s}$  can be maintained at Brandon for cooling purposes at Manitoba Hydro's thermal generating station,  $2.83 \text{ m}^3/\text{s}$  can be maintained for instream purposes at Headingley, and  $132\,000 \text{ dam}^3$  could be provided annually on an assured basis for consumptive uses. Since it was created, the reservoir has never been stressed from a water supply perspective, with the maximum recorded drawdown having been in preparation for flood inflows in 1979;
- With the Shellmouth Reservoir as presently operated, only 48% of the Assiniboine River's assured water supply capacity of  $132\,000 \text{ dam}^3$  has been licensed for consumptive use. An additional  $68\,000 \text{ dam}^3$  could be allocated before this capacity, as defined by inflows and weather conditions such as existed during the most severe drought on record (1937-42), would be fully utilized. It should be noted that under these conditions the Reservoir would only be fully utilized in one year (1942) during the entire period of record.
- There appears to be considerable confusion among residents along the river regarding how the Shellmouth Reservoir is operated, and about the amount of water that is available on an assured basis. Perceived historic shortages, most notably in 1988 and 1989, were not the result of insufficient water supplies, rather they were the result of difficulties in timing of releases from the reservoir and/or pump intake difficulties.
- Although Manitoba Water Resources does monitor new licensed water usage, there is limited factual data of overall water usage from the Assiniboine River. It is, therefore, difficult for water managers to make informed operating decisions, or to develop rational water management plans;
- Changing the operating regime of the Shellmouth Reservoir as studied herein would increase the Assiniboine River's water supply capability by



12 000 dam<sup>3</sup>. Such an operating change would allow the projected future demands to be met without lowering the reservoir beyond what current demands would require in the event of a drought such as occurred in 1937 to 1942.

- The increase in water supply capability attributable to scenarios Modified Base or Gated 1 is likely understated relative to how the scenarios were originally defined, because of the probability forecasting incorporated in them.
- Raising the winter drawdown level would result in some loss of downstream flood damage reduction benefits. These could for the most part be recovered through the retrofitting of gates on the currently ungated spillway. This was found to be technically and hydraulically feasible, and would cost in the range of one to two million dollars;
- The operating regime changes which were investigated would have little impact on existing recreation development along the reservoir shoreline. They could, however, impact negatively on flow regimes and agricultural land both above and below the reservoir. The Gated 1 scenario could increase the frequency and duration of backwater effects in the Kamsack, Saskatchewan area. This could impede local drainage on up to about 783 ha of cultivated land, possibly resulting in delays in seeding dates. Increased frequency and duration of at or near bankfull flows below the dam could also cause local drainage difficulties;
- Mercury concentrations in fish in the reservoir are near or in excess of limits allowed for human consumption. The operating regime changes investigated could contribute to a temporary increase in these levels. Given the current state of knowledge concerning this issue, quantitative assessments of this possibility could not be made. The reservoir's fishery could also be negatively affected by impacts on historic spawning areas and increased nutrient loadings. These would be most pronounced for Gated 1. The reservoir's increased water supply capability could lead to augmented river flows, resulting in an enhancement of the aquatic environment along the river in Manitoba;
- Examination of other factors which could impact on the Assiniboine River's water supply capability revealed that: a) although very unlikely, should Saskatchewan develop sufficient storage to be able to make use of its 50% share of Upper Assiniboine River runoff originating in Saskatchewan, the Shellmouth Reservoir would, under current consumptive demands and assumed minimum flow requirements at Brandon and Headingley, be drawndown to about 1 m below effective empty for both the Base and Modified Base operating modes. While in the strictest sense of the definition this would not be considered as



assuring demand conditions are met, it is likely that the reservoir successfully could be lowered to the required elevation, particularly during drought periods when adverse conditions are anticipated. Reducing the minimum flow requirement at Brandon to  $2.83 \text{ m}^3/\text{s}$  would sufficiently increase water supplies available for consumptive uses that even with Saskatchewan using its flow apportionment, estimated future demands could be met with existing operating rules.

### **Recommendations**

On the basis of the work done in this study, and on the above conclusions, it is recommended that:

1. A public information program be undertaken to:
  - inform residents along the Assiniboine River of its important role in southern Manitoba, how the Shellmouth Reservoir has changed its flow regime;
  - explain how and why the reservoir is presently operated;
  - present the findings of this study concerning the river's water supply capability and how it might be increased.
2. A water monitoring program be implemented to obtain data on actual water usage from the river and to ensure that all major usage is licensed and that licenses are adhered to.
3. Manitoba Water Resources consider establishing an Advisory Board which represents existing and potential users of Assiniboine River water to facilitate local input into water management along the Assiniboine River.
4. Mercury concentrations in fish in the reservoir continue to be monitored, and the bio-physical mechanisms of mercury production and uptake continue to be studied.
5. Should additional water supplies be required along the Assiniboine and the Modified Base or Gated 1 operating regimes be considered, additional studies should be carried out to:
  - examine in more detail the environmental issues identified in this report;
  - develop a solution, including possible purchase of affected lands, to perceived drainage problems in the Kamsack, Saskatchewan area;
  - explore further the retrofitting of spillway gates, particularly with regard to operating considerations and annual operating and maintenance costs.



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## Tables

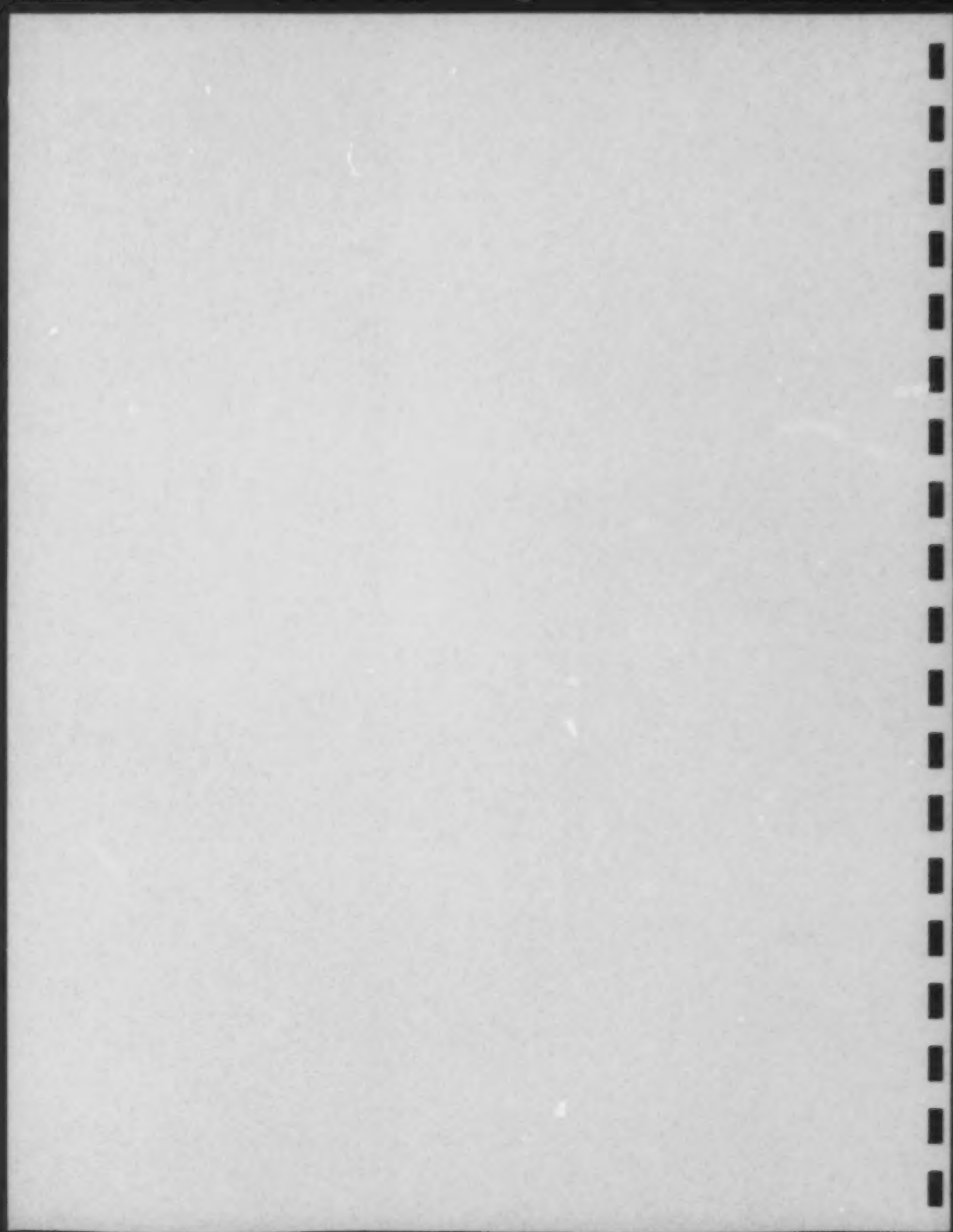


TABLE 1

Maximum and Minimum  
Flows at Brandon  
1970 to 1990

| Year | Annual Maximum in m <sup>3</sup> /s |             | Annual Minimum in m <sup>3</sup> /s |             |
|------|-------------------------------------|-------------|-------------------------------------|-------------|
|      | Recorded                            | Unregulated | Recorded                            | Unregulated |
| 1970 | 222                                 | 274         | 10.1                                | 7.1         |
| 1971 | 142                                 | 232         | 6.3                                 | 5.3         |
| 1972 | 221                                 | 286         | 5.1                                 | 2.0         |
| 1973 | 25                                  | 26          | 4.0                                 | 3.2         |
| 1974 | 309                                 | 389         | 12.2                                | 2.8         |
| 1975 | 261                                 | 387         | 17.5                                | 8.1         |
| 1976 | 617                                 | 649         | 15.2                                | 6.7         |
| 1977 | 21                                  | 39          | 7.3                                 | 3.3         |
| 1978 | 63                                  | 75          | 3.1                                 | 1.8         |
| 1979 | 314                                 | 401         | 7.6                                 | 2.0         |
| 1980 | 95                                  | 91          | 6.8                                 | 2.6         |
| 1981 | 26                                  | 27          | 2.4                                 | 2.1         |
| 1982 | 108                                 | 119         | 3.7                                 | 2.1         |
| 1983 | 190                                 | 216         | 8.3                                 | 2.6         |
| 1984 | 35                                  | 64          | 3.1                                 | 0.8         |
| 1985 | 141                                 | 239         | 8.5                                 | 2.1         |
| 1986 | 193                                 | 200         | 6.4                                 | 1.9         |
| 1987 | 225                                 | 237         | 8.5                                 | 2.3         |
| 1988 | 81                                  | 134         | 2.8                                 | 0.0         |
| 1989 | 28                                  | 27          | 1.9                                 | 0.0         |
| 1990 | 108                                 | 205         | 6.9                                 | 0.8         |

**TABLE 2****Maximum and Minimum  
Flows at Portage la Prairie  
1970 to 1990**

| Year | Annual Maximum in m <sup>3</sup> /s |             | Annual Minimum in m <sup>3</sup> /s |             |
|------|-------------------------------------|-------------|-------------------------------------|-------------|
|      | Recorded*                           | Unregulated | Recorded                            | Unregulated |
| 1970 | 432                                 | 465         | 13.8                                | 8.9         |
| 1971 | 216                                 | 296         | 12.9                                | 10.8        |
| 1972 | 331                                 | 391         | 12.5                                | 5.6         |
| 1973 | 62                                  | 59          | 9.9                                 | 6.1         |
| 1974 | 875                                 | 853         | 14.2                                | 2.8         |
| 1975 | 462                                 | 620         | 26.2                                | 14.3        |
| 1976 | 1350                                | 1390        | 12.1                                | 10.0        |
| 1977 | 50                                  | 47          | 12.7                                | 5.9         |
| 1978 | 156                                 | 155         | 10.7                                | 4.8         |
| 1979 | 550                                 | 551         | 9.9                                 | 2.8         |
| 1980 | 98                                  | 92          | 8.9                                 | 4.4         |
| 1981 | 47                                  | 40          | 8.8                                 | 5.4         |
| 1982 | 285                                 | 286         | 10.0                                | 3.9         |
| 1983 | 319                                 | 307         | 15.6                                | 12.7        |
| 1984 | 75                                  | 95          | 6.6                                 | 3.7         |
| 1985 | 256                                 | 259         | 12.7                                | 3.3         |
| 1986 | 299                                 | 281         | 10.0                                | 7.1         |
| 1987 | 389                                 | 392         | 8.7                                 | 2.9         |
| 1988 | 85                                  | 136         | 4.0                                 | 1.4         |
| 1989 | 173                                 | 148         | 4.9                                 | 1.4         |
| 1990 | 146                                 | 207         | 6.8                                 | 1.5         |

\*Combined flow from Assiniboine River near Portage la Prairie (05MJ003) and Portage Diversion near Portage la Prairie (05LL019)



TABLE 3

**Water Demands  
Shellmouth Reservoir to Brandon**

| Month        | Currently Licensed* |                  |                   |                  |                   |                  | Estimated Future* |                  |                   |                  |                   |                  |
|--------------|---------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|
|              | Irrigation          |                  | Mun. & Ind.       |                  | Total             |                  | Irrigation        |                  | Mun. & Ind.       |                  | Total             |                  |
|              | m <sup>3</sup> /s   | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> |
| January      |                     |                  | 0.178             | 478.             | 0.178             | 478.             |                   |                  | 0.320             | 857.             | 0.320             | 857.             |
| February     |                     |                  | 0.198             | 480.             | 0.198             | 480.             |                   |                  | 0.343             | 829.             | 0.343             | 829.             |
| March        |                     |                  | 0.190             | 508.             | 0.190             | 508.             |                   |                  | 0.343             | 918.             | 0.343             | 918.             |
| April        |                     |                  | 0.198             | 514.             | 0.198             | 514.             |                   |                  | 0.354             | 917.             | 0.354             | 917.             |
| May          | 0.125               | 334.             | 0.229             | 614.             | 0.354             | 948.             | 0.247             | 661.             | 0.413             | 1107.            | 0.660             | 1768.            |
| June         | 0.374               | 969.             | 0.328             | 851.             | 0.702             | 1820.            | 0.740             | 1918.            | 0.592             | 1534.            | 1.332             | 3452.            |
| July         | 0.467               | 1251.            | 0.255             | 683.             | 0.722             | 1934.            | 0.925             | 2477.            | 0.459             | 1229.            | 1.384             | 3708.            |
| August       | 0.374               | 1001.            | 0.255             | 683.             | 0.629             | 1684.            | 0.740             | 1982.            | 0.459             | 1229.            | 1.199             | 3211.            |
| September    | 0.125               | 323.             | 0.210             | 543.             | 0.334             | 866.             | 0.247             | 661.             | 0.379             | 984.             | 0.626             | 1623.            |
| October      |                     |                  | 0.190             | 508.             | 0.190             | 508.             |                   |                  | 0.343             | 918.             | 0.343             | 918.             |
| November     |                     |                  | 0.198             | 514.             | 0.198             | 514.             |                   |                  | 0.354             | 917.             | 0.354             | 917.             |
| December     |                     |                  | 0.178             | 478.             | 0.178             | 478.             |                   |                  | 0.320             | 857.             | 0.320             | 857.             |
| <b>TOTAL</b> |                     | <b>3878</b>      |                   | <b>6854</b>      |                   | <b>10732</b>     |                   | <b>7699</b>      |                   | <b>12296</b>     |                   | <b>19973</b>     |

\*Non-consumptive use at the Brandon Thermal Plant licensed at 5.66 m<sup>3</sup>/s (179 000 dam<sup>3</sup> per year), is not included in these numbers.

TABLE 4

**Water Demands  
Brandon to Portage la Prairie**

| Month        | Currently Licensed |                  |                   |                  |                   |                  | Estimated Future  |                  |                   |                  |                   |                  |
|--------------|--------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|
|              | Irrigation         |                  | Mun. & Ind.       |                  | Total             |                  | Irrigation        |                  | Mun. & Ind.*      |                  | Total             |                  |
|              | m <sup>3</sup> /s  | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> |
| January      |                    |                  | 0.085             | 228.             | 0.085             | 228.             |                   |                  | 0.745             | 1995.            | 0.745             | 1995.            |
| February     |                    |                  | 0.082             | 199.             | 0.082             | 199.             |                   |                  | 0.733             | 1774.            | 0.733             | 1774.            |
| March        |                    |                  | 0.085             | 228.             | 0.085             | 228.             |                   |                  | 0.745             | 1995.            | 0.745             | 1995.            |
| April        |                    |                  | 0.088             | 228.             | 0.088             | 228.             |                   |                  | 0.750             | 1945.            | 0.750             | 1945.            |
| May          | 0.436              | 1168.            | 0.105             | 281.             | 0.541             | 1449.            | 0.864             | 2313.            | 0.790             | 2116.            | 1.654             | 4429.            |
| June         | 1.308              | 3391.            | 0.099             | 257.             | 1.407             | 3648.            | 2.591             | 6716.            | 0.773             | 2004.            | 3.364             | 8720.            |
| July         | 1.638              | 4386.            | 0.102             | 273.             | 1.739             | 4659.            | 3.239             | 8675.            | 0.767             | 2055.            | 4.006             | 10730.           |
| August       | 1.308              | 3504.            | 0.102             | 273.             | 1.410             | 3777.            | 2.591             | 6940.            | 0.767             | 2055.            | 3.358             | 8995.            |
| September    | 0.436              | 1130.            | 0.093             | 242.             | 0.530             | 1372.            | 0.864             | 2239.            | 0.761             | 1974.            | 1.625             | 4213.            |
| October      |                    |                  | 0.102             | 273.             | 0.102             | 273.             |                   |                  | 0.767             | 2055.            | 0.767             | 2055.            |
| November     |                    |                  | 0.082             | 213.             | 0.082             | 213.             |                   |                  | 0.739             | 1916.            | 0.739             | 1916.            |
| December     |                    |                  | 0.074             | 197.             | 0.074             | 197.             |                   |                  | 0.722             | 1934.            | 0.722             | 1934.            |
| <b>TOTAL</b> |                    | <b>13579</b>     |                   | <b>2892</b>      |                   | <b>16471</b>     |                   | <b>26883</b>     |                   | <b>23820</b>     |                   | <b>50703</b>     |

\*Includes a reservation for the Pembina Valley Water Cooperative Inc. proposal to divert 0.566 m<sup>3</sup>/s.  
(17 860 dam<sup>3</sup> per year)

TABLE 5

**Water Demands  
Portage la Prairie to Winnipeg\***

| Month        | Currently Licensed |                  |                   |                  |                   |                  | Estimated Future  |                  |                   |                  |                   |                  |
|--------------|--------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|
|              | Irrigation         |                  | Mun. & Ind.**     |                  | Total             |                  | Irrigation        |                  | Mun. & Ind.**     |                  | Total             |                  |
|              | m <sup>3</sup> /s  | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> | m <sup>3</sup> /s | dam <sup>3</sup> |
| January      |                    |                  | 0.283             | 758.             | <b>0.283</b>      | <b>758.</b>      |                   |                  | 0.283             | 758.             | <b>0.283</b>      | <b>758.</b>      |
| February     |                    |                  | 0.283             | 685.             | <b>0.283</b>      | <b>685.</b>      |                   |                  | 0.283             | 685.             | <b>0.283</b>      | <b>685.</b>      |
| March        |                    |                  | 0.283             | 758.             | <b>0.283</b>      | <b>758.</b>      |                   |                  | 0.283             | 758.             | <b>0.283</b>      | <b>758.</b>      |
| April        |                    |                  | 0.283             | 734.             | <b>0.283</b>      | <b>734.</b>      |                   |                  | 0.283             | 734.             | <b>0.283</b>      | <b>734.</b>      |
| May          | 0.317              | 849.             | 1.416             | 3792.            | <b>1.733</b>      | <b>4641.</b>     | 0.628             | 1682.            | 1.416             | 3792.            | <b>2.044</b>      | <b>5474.</b>     |
| June         | 0.951              | 2466.            | 1.416             | 3670.            | <b>2.367</b>      | <b>6136.</b>     | 1.884             | 4884.            | 1.416             | 3670.            | <b>3.300</b>      | <b>8554.</b>     |
| July         | 1.191              | 3190.            | 1.416             | 3792.            | <b>2.607</b>      | <b>6982.</b>     | 2.358             | 6317.            | 1.416             | 3792.            | <b>3.774</b>      | <b>10109.</b>    |
| August       | 0.951              | 2548.            | 1.416             | 3792.            | <b>2.367</b>      | <b>6340.</b>     | 1.884             | 5047.            | 1.416             | 3792.            | <b>3.300</b>      | <b>8839.</b>     |
| September    | 0.317              | 822.             | 1.416             | 3670.            | <b>1.733</b>      | <b>4492.</b>     | 0.628             | 1628.            | 1.416             | 3670.            | <b>2.044</b>      | <b>5298.</b>     |
| October      |                    |                  | 1.416             | 3792.            | <b>1.416</b>      | <b>3792.</b>     |                   |                  | 1.416             | 3792.            | <b>1.416</b>      | <b>3792.</b>     |
| November     |                    |                  | 0.283             | 734.             | <b>0.283</b>      | <b>734.</b>      |                   |                  | 0.283             | 734.             | <b>0.283</b>      | <b>734.</b>      |
| December     |                    |                  | 0.283             | 758.             | <b>0.283</b>      | <b>758.</b>      |                   |                  | 0.283             | 758.             | <b>0.283</b>      | <b>758.</b>      |
| <b>TOTAL</b> |                    | <b>9875</b>      |                   | <b>26935</b>     |                   | <b>36810</b>     |                   | <b>19558</b>     |                   | <b>26935</b>     |                   | <b>46493</b>     |

\*Additionally, 2.83 m<sup>3</sup>/s (89 000 dam<sup>3</sup> per year) is normally made available for instream purposes at Headingley  
- includes City of Winnipeg.

\*\*Assiniboine River to La Salle Diversion.

**TABLE 6**  
**Water Supply Analysis Results**

|                                 | BASE                                       | MODIFIED BASE                              | GATED 1                                    |
|---------------------------------|--------------------------------------------|--------------------------------------------|--------------------------------------------|
| Maximum Water Supply Available* | 132 000 dam <sup>3</sup>                   | 144 000 dam <sup>3</sup>                   | 144 000 dam <sup>3</sup>                   |
| Difference                      | ---                                        | 12 000 dam <sup>3</sup>                    | 12 000 dam <sup>3</sup>                    |
| Minimum Reservoir Levels:       |                                            |                                            |                                            |
| - Current Licensed Demands      | 421.809 m<br>(117 100 dam <sup>3</sup> )** | 423.211 m<br>(171 100 dam <sup>3</sup> )** | 423.211 m<br>(171 100 dam <sup>3</sup> )** |
| - Estimated Future Demands      | 420.519 m<br>(78 300 dam <sup>3</sup> )**  | 421.736<br>(114 700 dam <sup>3</sup> )**   | 421.736<br>(114 700 dam <sup>3</sup> )**   |

\* With reservoir drawdown to elevation 419.7 (57 000 dam<sup>3</sup>).

\*\*Volumes of water remaining in the reservoir at indicated reservoir level.

TABLE 7

**Shellmouth Reservoir Maximum Daily Outflows\* in m<sup>3</sup>/s  
(Current Demands)**

| Year    | Base Peak | Modified Base |          | Gated 1 |          |
|---------|-----------|---------------|----------|---------|----------|
|         |           | Peak          | Change % | Peak    | Change % |
| 1913    | 125.45    | 160.02        | 27.56    | 156.85  | 25.03    |
| 1914    | 70.71     | 70.79         | 0.12     | 42.48   | -39.93   |
| 1917    | 42.48     | 70.79         | 66.67    | 42.48   | 0.00     |
| 1920    | 106.45    | 155.77        | 46.34    | 92.00   | -13.57   |
| 1921    | 97.41     | 108.20        | 11.08    | 126.47  | 29.83    |
| 1922    | 436.57    | 449.99        | 3.07     | 460.44  | 5.47     |
| 1923    | 210.74    | 243.87        | 15.72    | 272.70  | 29.40    |
| 1925    | 42.79     | 67.20         | 57.05    | 42.48   | -0.73    |
| 1927    | 201.93    | 211.98        | 4.98     | 227.42  | 12.62    |
| 1948    | 97.64     | 160.96        | 64.85    | 157.25  | 61.05    |
| 1954    | 155.38    | 188.57        | 21.36    | 241.18  | 55.22    |
| 1955    | 211.81    | 227.84        | 7.57     | 277.26  | 30.90    |
| 1956    | 130.23    | 188.96        | 45.10    | 201.90  | 55.03    |
| 1957    | 55.08     | 70.79         | 28.53    | 42.48   | -22.88   |
| 1971    | 42.48     | 70.79         | 66.67    | 42.48   | 0.00     |
| 1972    | 62.55     | 101.38        | 62.06    | 65.10   | 4.07     |
| 1974    | 57.68     | 95.03         | 64.75    | 69.63   | 20.72    |
| 1975    | 78.18     | 145.83        | 86.53    | 78.01   | -0.22    |
| 1976    | 70.79     | 117.43        | 65.88    | 64.79   | -8.48    |
| 1979    | 70.79     | 125.67        | 77.52    | 86.20   | 21.76    |
| 1985    | 42.48     | 70.79         | 66.67    | 42.48   | 0.00     |
| Average |           |               | 42.38    |         | 12.63    |

\*For years greater than 42.47 m<sup>3</sup>/s, the downstream channel capacity.

**TABLE 8**

**Shellmouth Reservoir  
Flood Routing Results**

|                                  | Base    | Modified Base | Gated 1 |
|----------------------------------|---------|---------------|---------|
| Peak Level (m):                  |         |               |         |
| a) Spring Flood                  |         |               |         |
| 1:50 year                        | 430.807 | 431.009       | 431.176 |
| 1:100 year                       | 431.149 | 431.322       | 431.374 |
| 1:500 year                       | 431.828 | 431.975       | 431.999 |
| 1:1000 year                      | 432.152 | 432.286       | 432.310 |
| b) Summer Flood                  |         |               |         |
| 1:50 year                        | 430.100 | 430.100       | 431.073 |
| 1:100 year                       | 430.393 | 430.393       | 431.112 |
| 1:500 year                       | 431.091 | 431.091       | 431.262 |
| 1:1000 year                      | 431.383 | 431.383       | 431.435 |
| Peak Outflow (m <sup>3</sup> /s) |         |               |         |
| a) Spring Flood                  |         |               |         |
| 1:50 year                        | 224     | 271           | 306     |
| 1:100 year                       | 302     | 344           | 362     |
| 1:500 year                       | 507     | 557           | 566     |
| 1:1000 year                      | 620     | 666           | 677     |
| b) Summer Flood                  |         |               |         |
| 1:50 year                        | 81      | 81            | 60      |
| 1:100 year                       | 136     | 136           | 125     |
| 1:500 year                       | 289     | 289           | 326     |
| 1:1000 year                      | 364     | 364           | 381     |



**TABLE 9**

**Shellmouth Reservoir Average Mean Monthly Flows in m<sup>3</sup>/s  
(For Currently Licensed Demands, 1913 to 1990)**

| Month     | Base | Modified<br>Base | Gated 1 |
|-----------|------|------------------|---------|
| January   | 7.5  | 4.9              | 5.3     |
| February  | 12.4 | 5.1              | 5.4     |
| March     | 13.3 | 4.9              | 5.3     |
| April     | 7.3  | 16.1             | 14.3    |
| May       | 32.5 | 41.7             | 35.7    |
| June      | 23.8 | 26.8             | 24.8    |
| July      | 17.8 | 19.7             | 20.4    |
| August    | 9.7  | 10.0             | 13.5    |
| September | 5.7  | 5.8              | 8.1     |
| October   | 4.8  | 4.8              | 5.7     |
| November  | 7.6  | 5.9              | 6.0     |
| December  | 7.8  | 5.0              | 5.3     |

TABLE 10

Annual Peak Discharge at Miniota in  $\text{m}^3/\text{s}^*$   
(1961 to 1990)\*\*

| Year    | Base Peak | Modified Base |        |         | Gated 1 |        |         |
|---------|-----------|---------------|--------|---------|---------|--------|---------|
|         |           | Peak          | Change | Percent | Peak    | Change | Percent |
| 1969    | 264.27    | 264.10        | -0.17  | -0.06   | 264.10  | -0.17  | -0.06   |
| 1972    | 152.26    | 150.24        | -2.02  | -1.33   | 150.16  | -2.10  | -1.38   |
| 1974    | 226.54    | 226.54        | 0.00   | 0.00    | 226.54  | 0.00   | 0.00    |
| 1975    | 175.29    | 215.11        | 39.82  | 22.71   | 185.60  | 10.31  | 5.88    |
| 1976    | 423.23    | 420.37        | -2.86  | -0.68   | 420.37  | -2.86  | -0.68   |
| 1979    | 216.31    | 218.40        | 2.09   | 0.97    | 218.40  | 2.09   | 0.97    |
| 1986    | 171.38    | 163.80        | -7.58  | -4.42   | 163.80  | -7.58  | -4.42   |
| Average |           |               |        | 2.46    |         |        | 0.04    |

\*years above bankfull capacity of  $152 \text{ m}^3/\text{s}$

\*\*Flow records only available since 1961.

TABLE 11

Annual Peak Discharge at Brandon in m<sup>3</sup>/s\*  
(1913 to 1990)

| Year    | Base Peak | Modified Base |        |         | Gated 1 |        |         |
|---------|-----------|---------------|--------|---------|---------|--------|---------|
|         |           | Peak          | Change | Percent | Peak    | Change | Percent |
| 1913    | 230.35    | 300.05        | 69.70  | 30.26   | 270.26  | 39.91  | 17.32   |
| 1916    | 243.94    | 241.96        | -1.98  | -0.81   | 241.96  | -1.98  | -0.81   |
| 1922    | 429.52    | 450.53        | 21.01  | 4.89    | 467.38  | 37.86  | 8.81    |
| 1923    | 407.91    | 425.27        | 17.36  | 4.26    | 425.27  | 17.36  | 4.26    |
| 1925    | 274.74    | 256.44        | -18.30 | -6.66   | 256.44  | -18.30 | -6.66   |
| 1927    | 353.32    | 368.41        | 15.09  | 4.27    | 341.88  | -11.44 | -3.24   |
| 1928    | 172.89    | 173.56        | 0.67   | 0.39    | 170.50  | -2.38  | -1.38   |
| 1936    | 240.81    | 240.13        | -0.68  | -0.28   | 240.13  | -0.68  | -0.28   |
| 1946    | 187.77    | 186.68        | -1.08  | -0.58   | 186.68  | -1.08  | -0.58   |
| 1947    | 294.22    | 297.64        | 3.43   | 1.16    | 297.64  | 3.43   | 1.16    |
| 1948    | 319.05    | 349.89        | 30.84  | 9.67    | 349.89  | 30.84  | 9.67    |
| 1951    | 189.24    | 188.48        | -0.76  | -0.40   | 188.48  | -0.76  | -0.40   |
| 1954    | 294.95    | 329.84        | 34.89  | 11.83   | 330.18  | 35.23  | 11.94   |
| 1955    | 419.04    | 454.72        | 35.68  | 8.51    | 417.99  | -1.05  | -0.25   |
| 1956    | 299.09    | 319.70        | 20.62  | 6.89    | 300.31  | 1.22   | 0.41    |
| 1960    | 233.85    | 233.18        | -0.67  | -0.29   | 233.18  | -0.67  | -0.29   |
| 1965    | 186.00    | 185.99        | -0.01  | -0.01   | 185.99  | -0.01  | -0.01   |
| 1969    | 354.19    | 352.47        | -1.73  | -0.49   | 352.47  | -1.73  | -0.49   |
| 1970    | 185.41    | 208.71        | 23.30  | 12.57   | 208.71  | 23.30  | 12.57   |
| 1972    | 213.58    | 211.04        | -2.54  | -1.19   | 211.04  | -2.54  | -1.19   |
| 1974    | 279.35    | 279.24        | -0.11  | -0.04   | 279.24  | -0.11  | -0.04   |
| 1975    | 250.02    | 258.10        | 8.08   | 3.23    | 256.58  | 6.56   | 2.62    |
| 1976    | 594.83    | 593.11        | -1.73  | -0.29   | 592.65  | -2.18  | -0.37   |
| 1979    | 272.28    | 274.33        | 2.05   | 0.75    | 274.33  | 2.05   | 0.75    |
| 1983    | 184.30    | 184.29        | -0.01  | 0.00    | 184.29  | -0.01  | 0.00    |
| 1986    | 192.33    | 179.18        | -13.15 | -6.84   | 179.18  | -13.15 | -6.84   |
| 1987    | 220.89    | 220.19        | -0.70  | -0.32   | 220.19  | -0.70  | -0.32   |
| Average |           |               |        | 1.07    |         |        | 0.62    |

\*years above bankfull capacity of 170 m<sup>3</sup>/s

TABLE 12

Annual Peak Discharge at Portage la Prairie in m<sup>3</sup>/s\*  
(1913 to 1990)

| Year    | Base Peak | Modified Base |        |         | Gated 1 |        |         |
|---------|-----------|---------------|--------|---------|---------|--------|---------|
|         |           | Peak          | Change | Percent | Peak    | Change | Percent |
| 1916    | 626.72    | 624.91        | -1.81  | -0.29   | 624.91  | -1.81  | -0.29   |
| 1922    | 467.01    | 496.91        | 29.90  | 6.40    | 510.48  | 43.47  | 9.31    |
| 1923    | 525.66    | 525.66        | 0.00   | 0.00    | 525.66  | 0.00   | 0.00    |
| 1927    | 447.58    | 454.01        | 6.43   | 1.44    | 431.93  | -15.66 | -3.50   |
| 1936    | 430.65    | 431.98        | 1.33   | 0.31    | 431.98  | 1.33   | 0.31    |
| 1955    | 516.42    | 545.53        | 29.11  | 5.64    | 517.64  | 1.22   | 0.24    |
| 1956    | 665.01    | 661.38        | -3.62  | -0.55   | 661.38  | -3.62  | -0.55   |
| 1960    | 576.57    | 572.86        | -3.71  | -0.64   | 572.86  | -3.71  | -0.64   |
| 1965    | 437.22    | 436.68        | -0.54  | -0.12   | 436.68  | -0.54  | -0.12   |
| 1969    | 670.56    | 656.62        | -13.93 | -2.08   | 656.62  | -13.93 | -2.08   |
| 1970    | 428.98    | 428.75        | -0.23  | -0.05   | 428.75  | -0.23  | -0.05   |
| 1974    | 875.72    | 874.44        | -1.27  | -0.15   | 874.44  | -1.27  | -0.15   |
| 1975    | 450.05    | 470.04        | 19.99  | 4.44    | 463.22  | 13.17  | 2.93    |
| 1976    | 1332.87   | 1328.79       | -4.08  | -0.31   | 1328.40 | -4.47  | -0.34   |
| 1979    | 524.69    | 526.00        | 1.30   | 0.25    | 526.00  | 1.30   | 0.25    |
| Average |           |               |        | 0.22    |         |        | 0.08    |

\*years above bankfull capacity of 425 m<sup>3</sup>/s

TABLE 13

**Shellmouth Reservoir Average Mean Monthly Water Levels in Metres  
(1913 to 1990)**

| Month     | Current Demands |               |         | Future Demands |               |         |
|-----------|-----------------|---------------|---------|----------------|---------------|---------|
|           | Base            | Modified Base | Gated 1 | Base           | Modified Base | Gated 1 |
| January   | 426.366         | 426.762       | 426.811 | 426.262        | 426.631       | 426.678 |
| February  | 425.942         | 426.597       | 426.631 | 425.841        | 426.460       | 426.497 |
| March     | 425.354         | 426.451       | 426.469 | 425.268        | 426.317       | 426.335 |
| April     | 425.847         | 427.024       | 427.051 | 425.780        | 426.911       | 426.936 |
| May       | 427.640         | 428.082       | 428.277 | 427.579        | 427.993       | 428.185 |
| June      | 427.688         | 427.902       | 428.261 | 427.627        | 427.816       | 428.173 |
| July      | 427.524         | 427.646       | 428.024 | 427.451        | 427.548       | 427.926 |
| August    | 427.289         | 427.387       | 427.661 | 427.198        | 427.271       | 427.548 |
| September | 427.088         | 427.179       | 427.320 | 426.984        | 427.054       | 427.198 |
| October   | 426.993         | 427.082       | 427.161 | 426.887        | 426.957       | 427.036 |
| November  | 426.896         | 427.027       | 427.085 | 426.789        | 426.902       | 426.960 |
| December  | 426.670         | 426.920       | 426.972 | 426.567        | 426.792       | 426.847 |

**TABLE 14**

**Maximum Water Levels near Kamsack (SE 48-29-13 WPM)  
Post May 1st Flood Years  
(Current Demands 1944 to 1990)**

| Year | Maximum Water Level<br>in metres |                  |         | Increase above<br>Base Condition<br>in metres |         |
|------|----------------------------------|------------------|---------|-----------------------------------------------|---------|
|      | Base                             | Modified<br>Base | Gated 1 | Modified<br>Base                              | Gated 1 |
| 1948 | 432.073                          | 432.073          | 432.073 | 0.000                                         | 0.000   |
| 1951 | 430.348                          | 432.352          | 430.352 | 0.004                                         | 0.004   |
| 1954 | 431.449                          | 431.466          | 431.478 | 0.017                                         | 0.029   |
| 1955 | 432.269                          | 432.269          | 432.269 | 0.000                                         | 0.000   |
| 1956 | 432.093                          | 432.093          | 432.093 | 0.000                                         | 0.000   |
| 1957 | 431.860                          | 431.860          | 431.860 | 0.000                                         | 0.000   |
| 1960 | 430.348                          | 430.488          | 430.505 | 0.140                                         | 0.157   |
| 1967 | 430.939                          | 430.995          | 430.995 | 0.058                                         | 0.058   |
| 1971 | 430.808                          | 430.956          | 431.098 | 0.148                                         | 0.290   |
| 1972 | 432.000                          | 431.200          | 431.200 | 0.000                                         | 0.000   |
| 1974 | 431.927                          | 431.927          | 431.927 | 0.000                                         | 0.000   |
| 1975 | 432.226                          | 432.226          | 432.226 | 0.000                                         | 0.000   |
| 1976 | 431.302                          | 431.431          | 431.578 | 0.129                                         | 0.590   |
| 1979 | 432.239                          | 432.239          | 432.239 | 0.000                                         | 0.000   |
| 1983 | 431.712                          | 431.712          | 431.712 | 0.000                                         | 0.000   |
| 1985 | 431.362                          | 431.454          | 431.536 | 0.092                                         | 0.174   |
| 1988 | 430.391                          | 430.395          | 430.422 | 0.004                                         | 0.031   |



TABLE 15

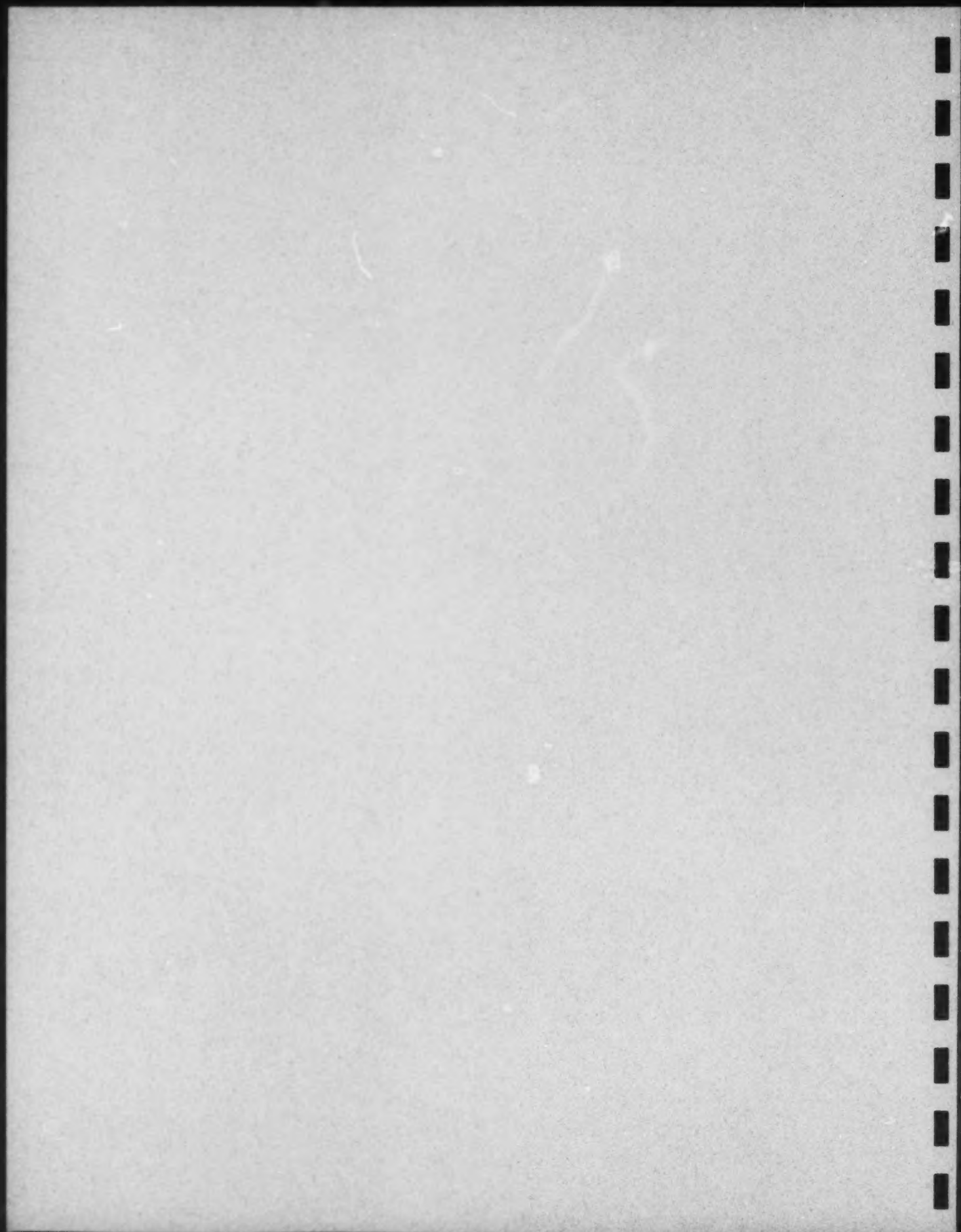
**Lost Seeding Opportunity near Kamsack  
(SE 18-29-13 WPM)**

| Year | Seeding Opportunity in Days<br>After May 1 |                  |         | Lost Seeding<br>Opportunity<br>in Days |         |
|------|--------------------------------------------|------------------|---------|----------------------------------------|---------|
|      | Base                                       | Modified<br>Base | Gated 1 | Modified<br>Base                       | Gated 1 |
| 1948 | 2                                          | 1                | 0       | 1                                      | 2       |
| 1951 | 19                                         | 19               | 19      | 0                                      | 0       |
| 1954 | 4                                          | 3                | 0       | 1                                      | 4       |
| 1955 | 0                                          | 0                | 0       | 0                                      | 0       |
| 1956 | 0                                          | 0                | 0       | 0                                      | 0       |
| 1957 | 19                                         | 18               | 0       | 1                                      | 19      |
| 1960 | 30                                         | 30               | 29      | 0                                      | 1       |
| 1967 | 18                                         | 17               | 17      | 1                                      | 1       |
| 1971 | 28                                         | 27               | 19      | 1                                      | 9       |
| 1972 | 12                                         | 7                | 0       | 5                                      | 12      |
| 1974 | 0                                          | 0                | 0       | 0                                      | 0       |
| 1975 | 5                                          | 4                | 0       | 1                                      | 5       |
| 1976 | 23                                         | 20               | 0       | 3                                      | 23      |
| 1979 | 2                                          | 0                | 0       | 2                                      | 2       |
| 1983 | 25                                         | 24               | 24      | 1                                      | 1       |
| 1985 | 25                                         | 21               | 0       | 4                                      | 25      |
| 1988 | 25                                         | 25               | 25      | 0                                      | 0       |



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## Figures



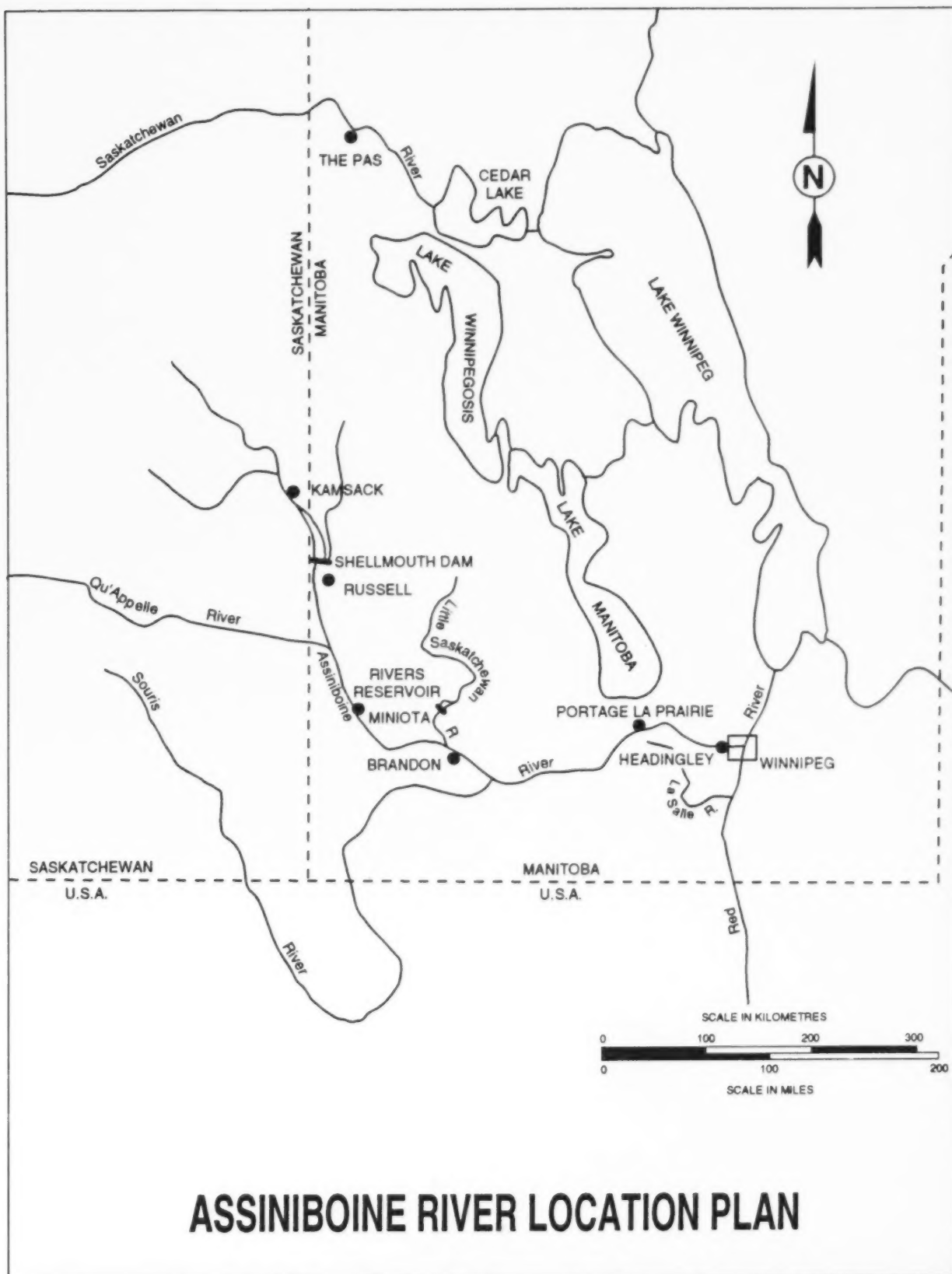
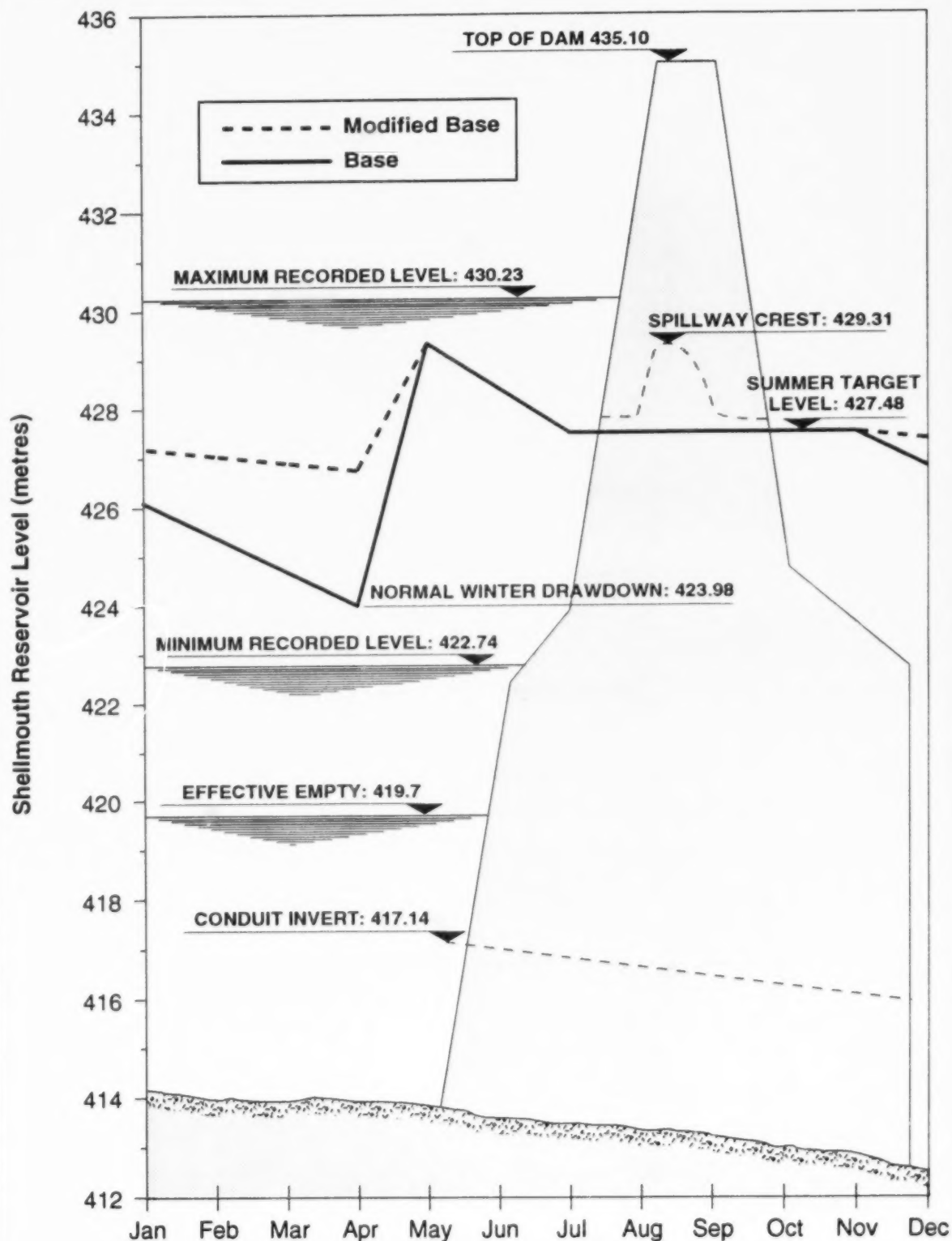
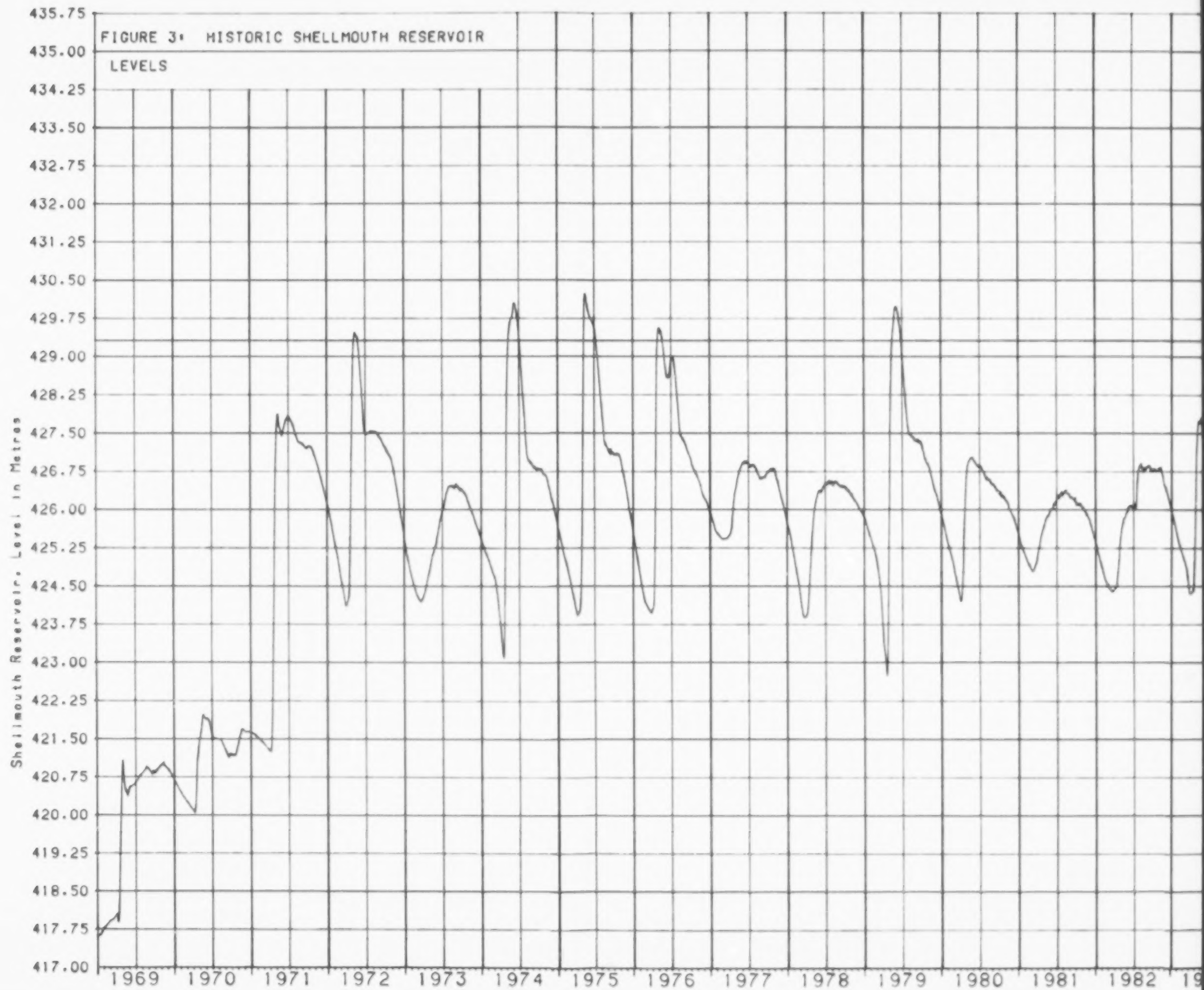


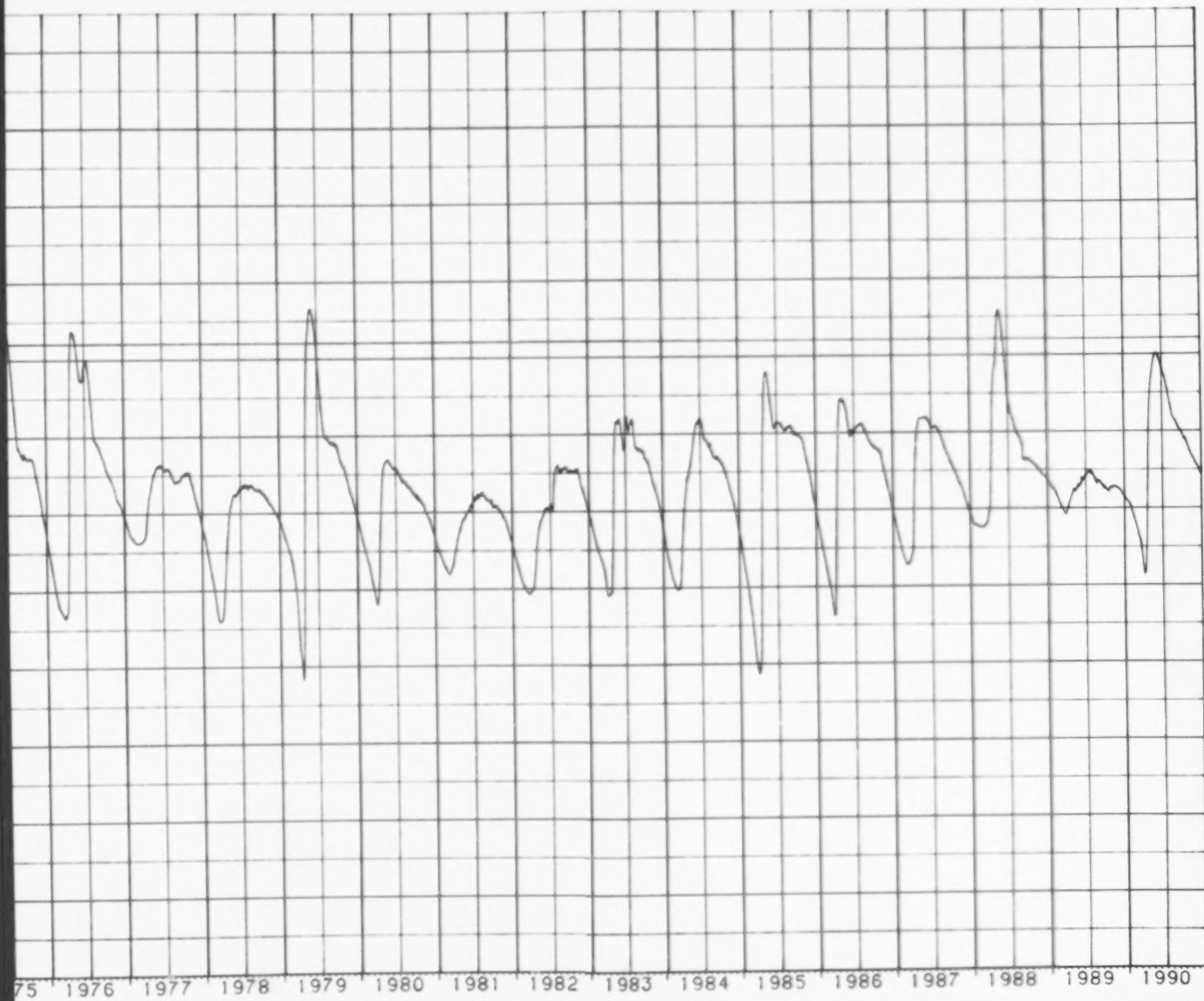
**Figure 1**



**GENERALIZED RESERVOIR OPERATING REGIMES**  
(Beginning of Month Target Levels)







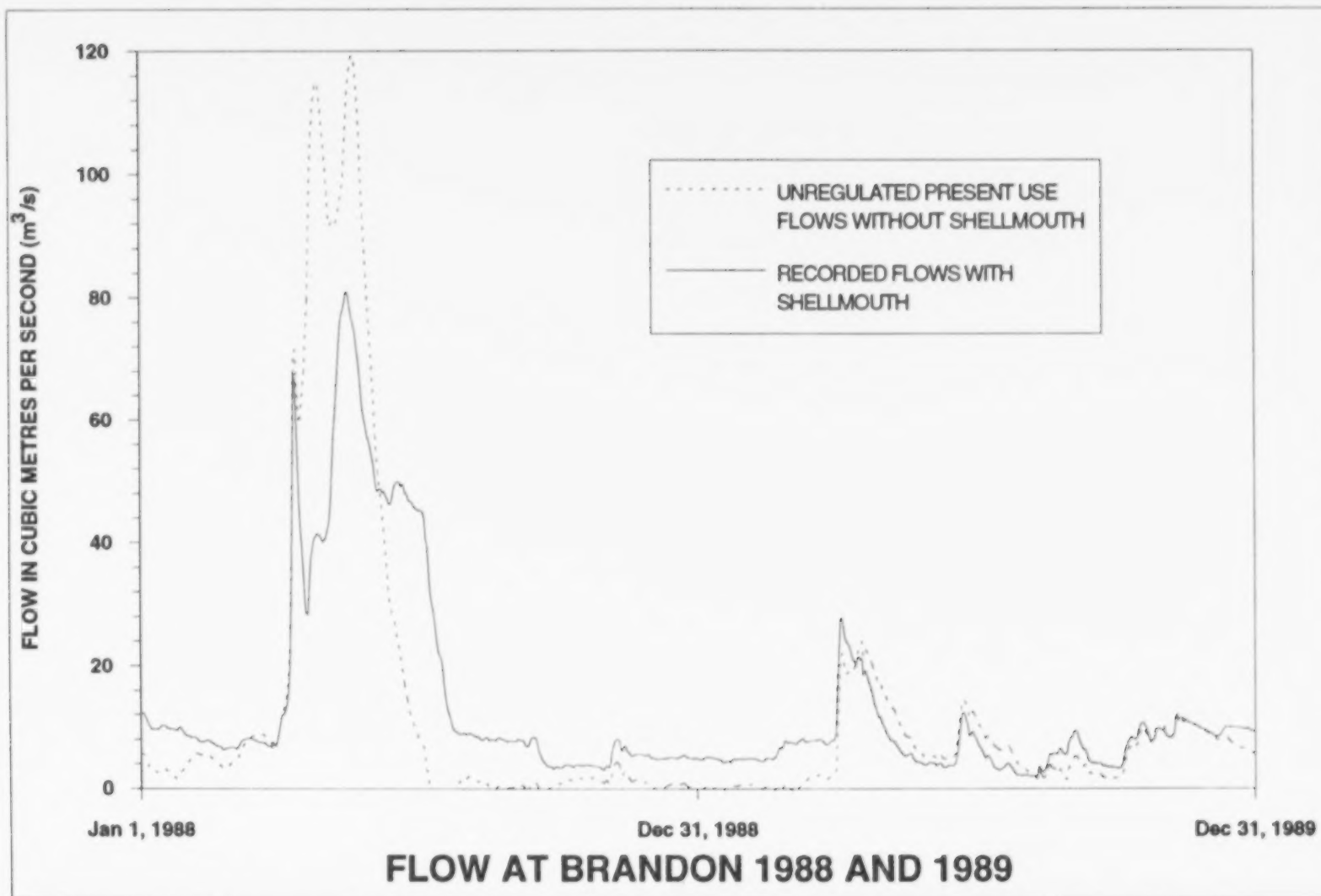


Figure 4

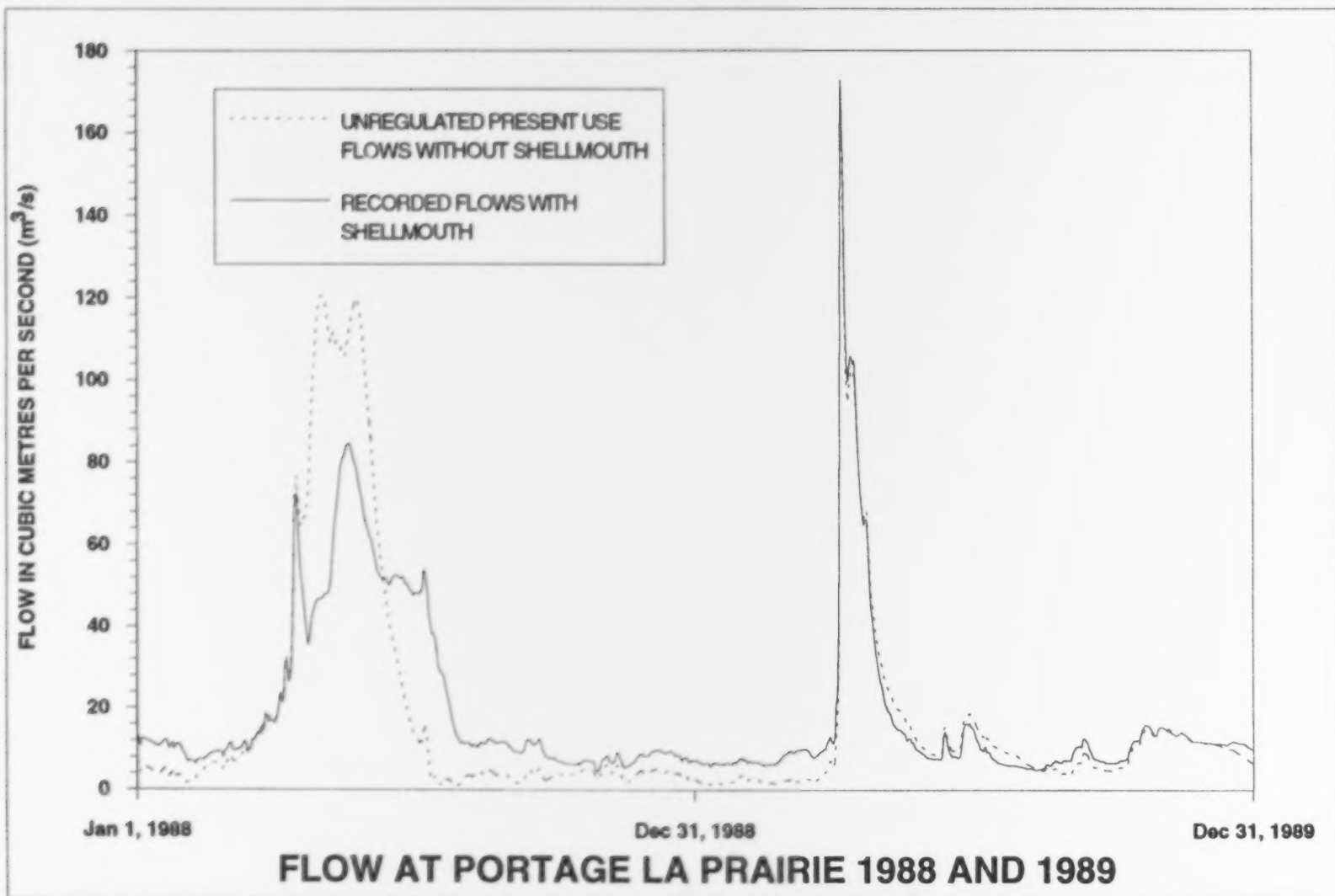


Figure 5

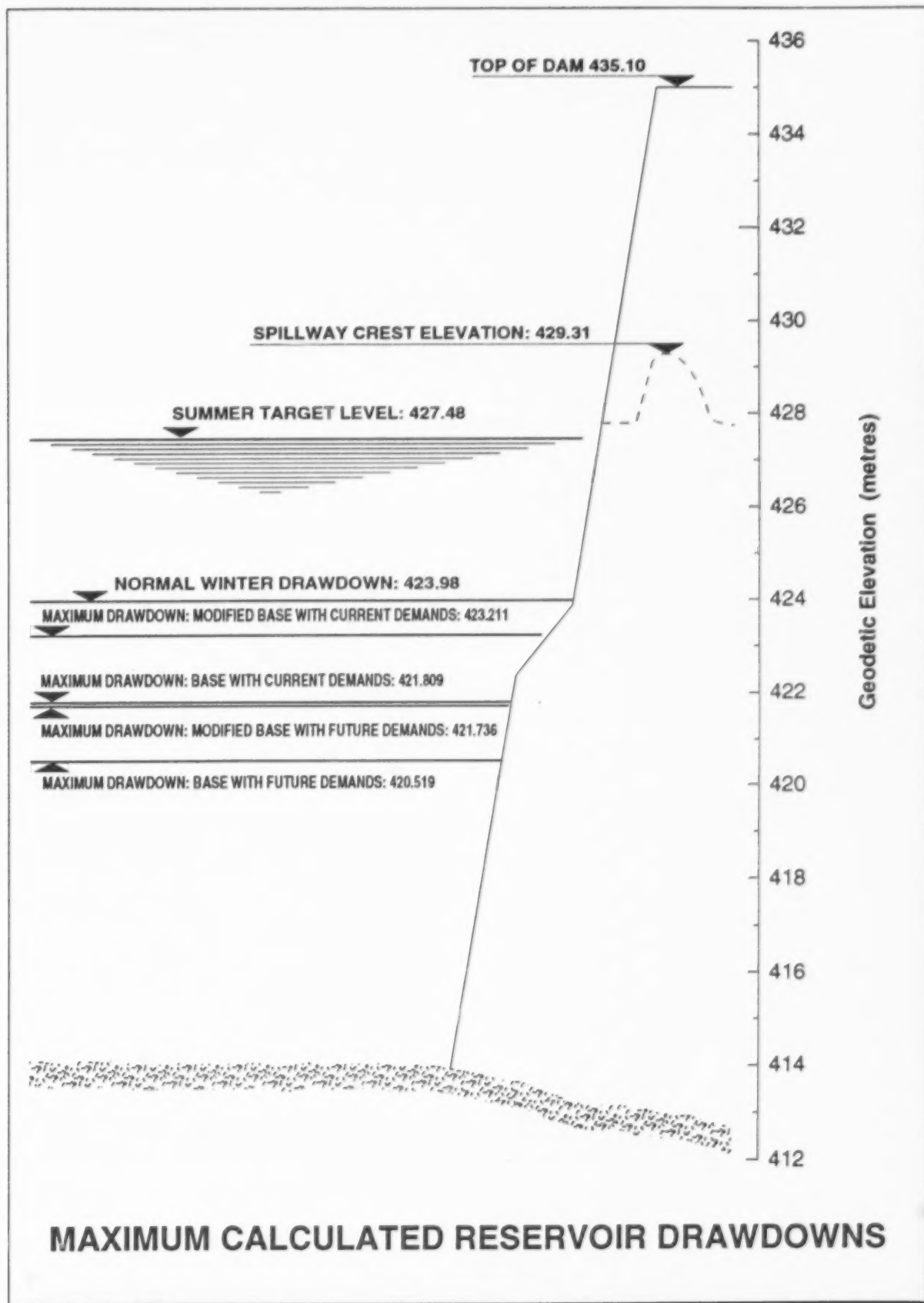


Figure 6



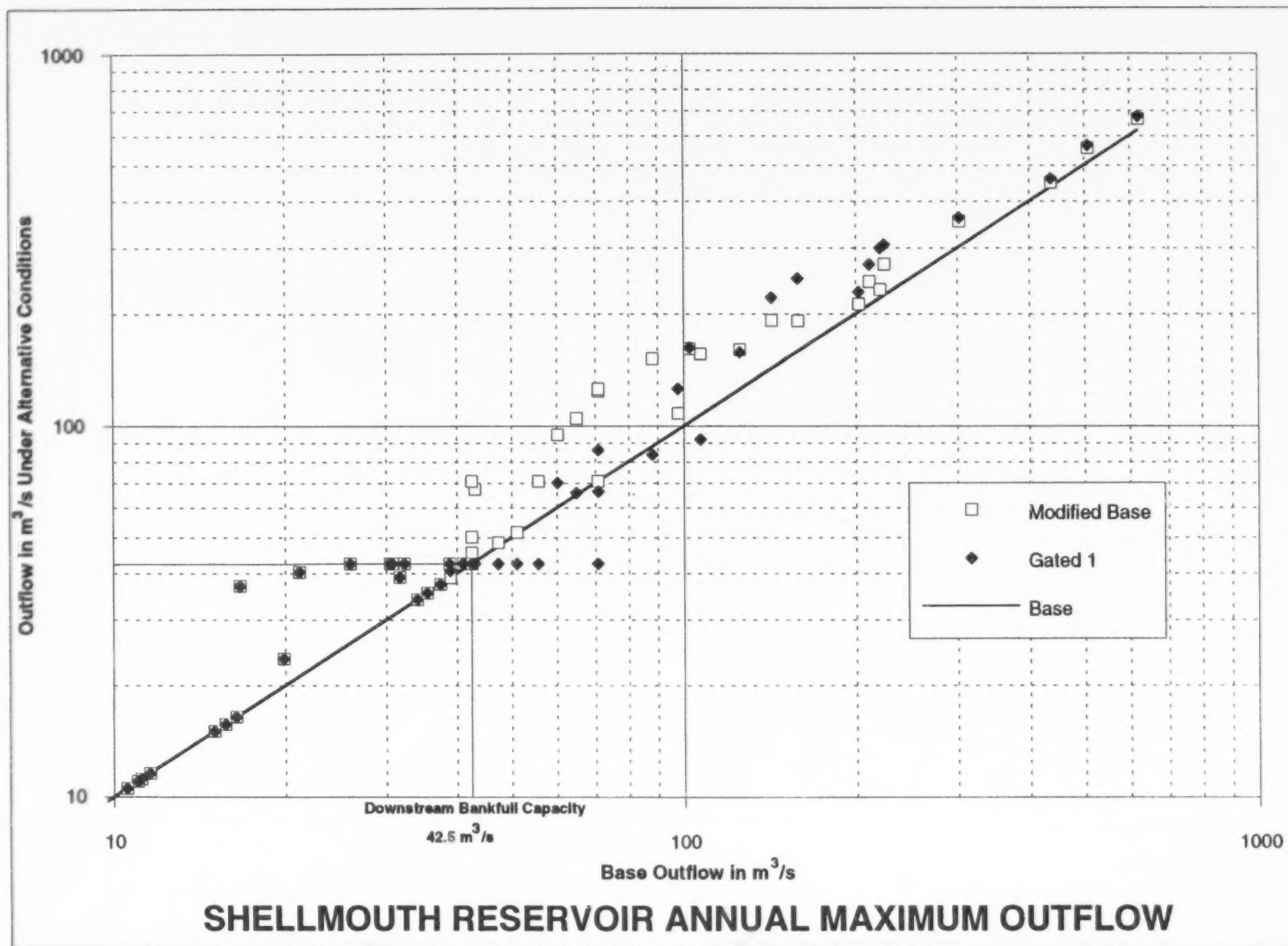


Figure 7



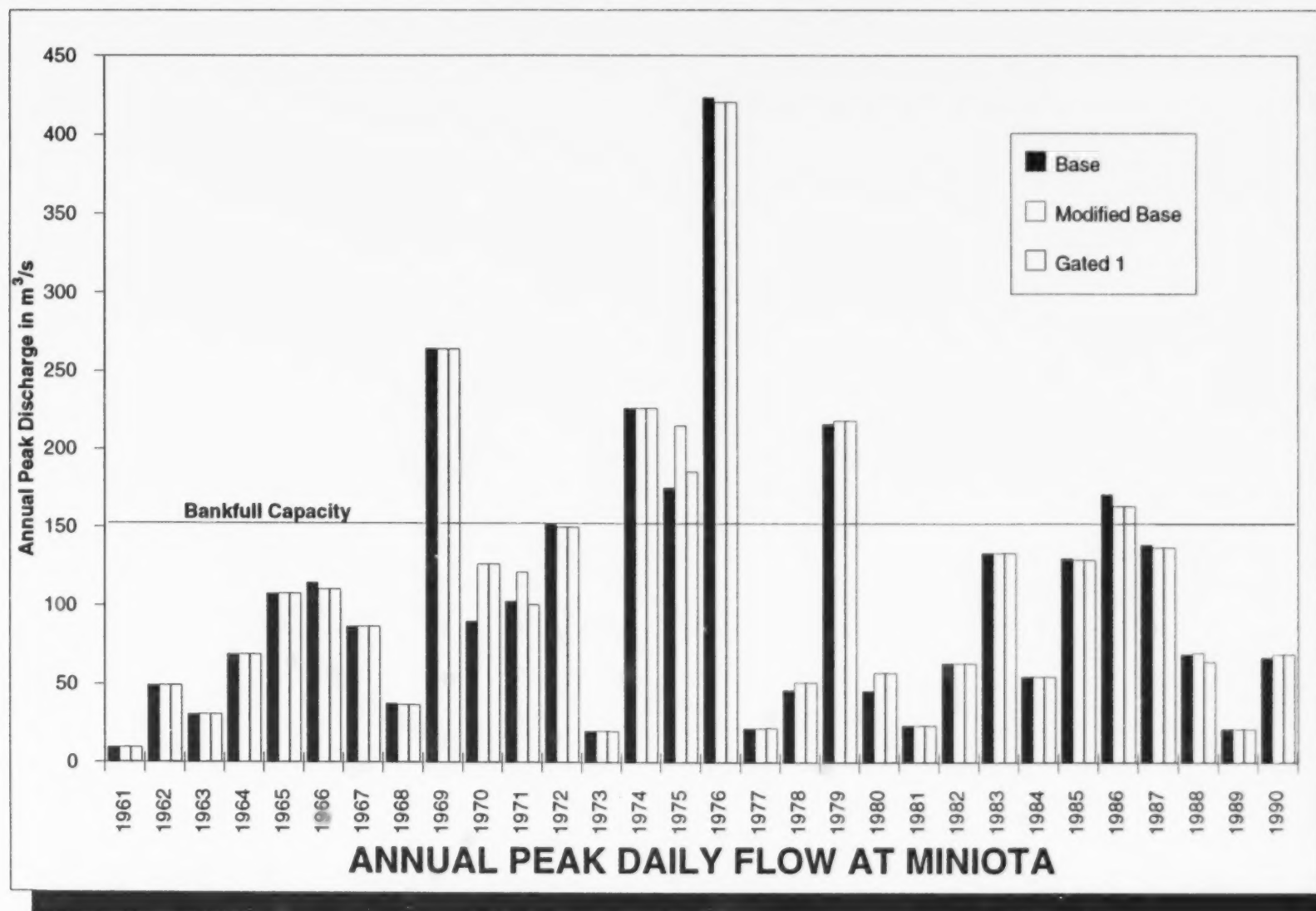


Figure 8

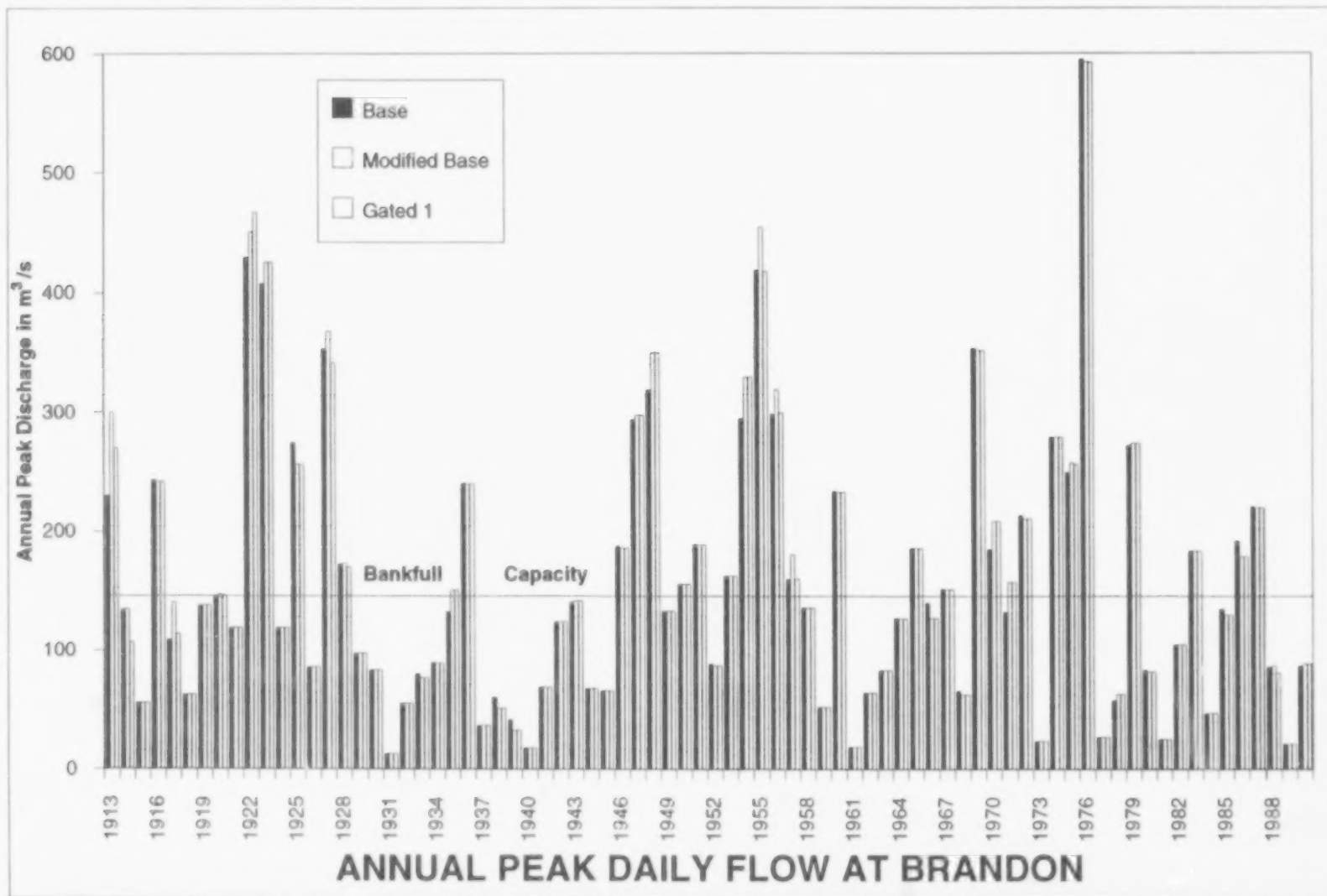


Figure 9

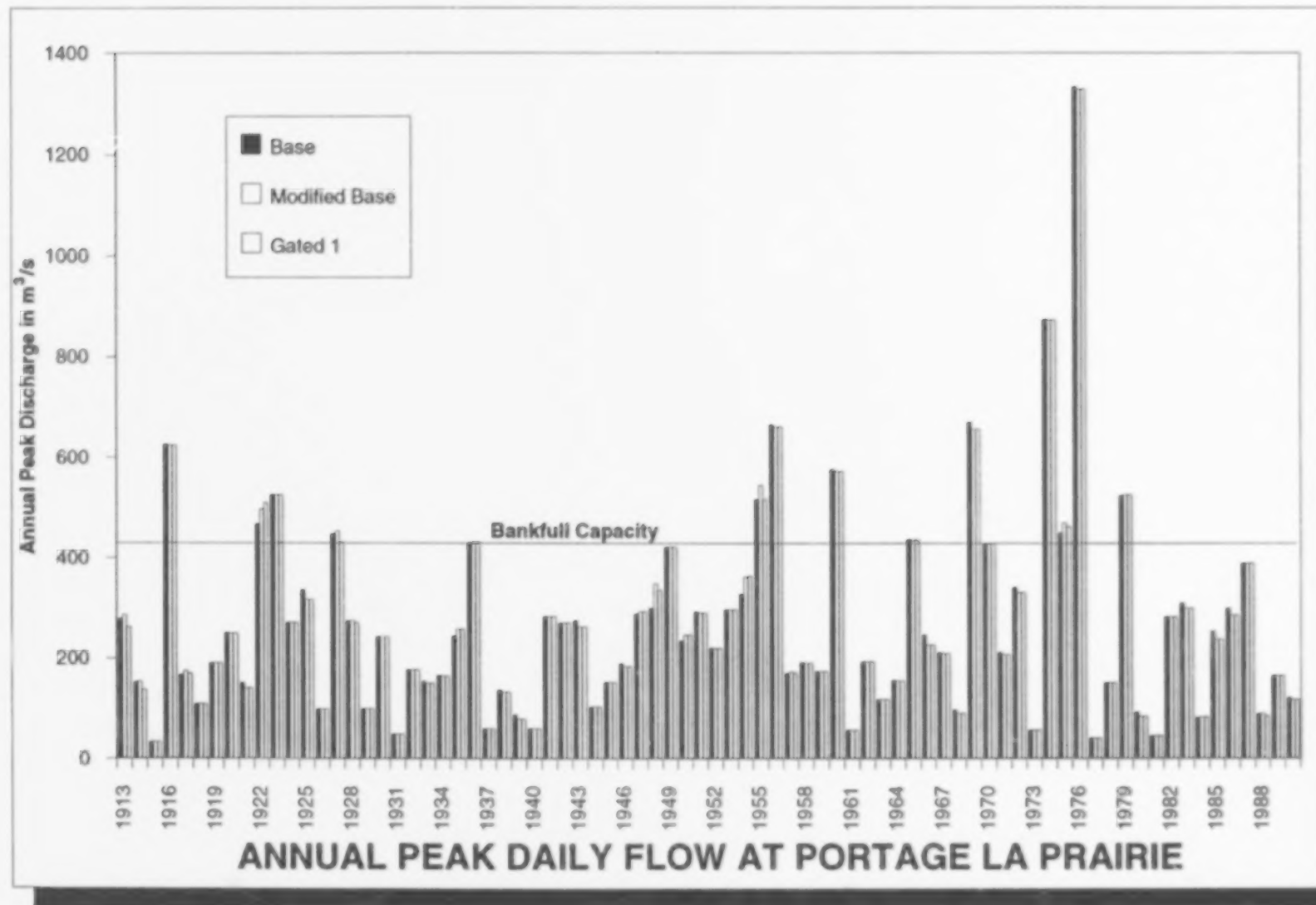
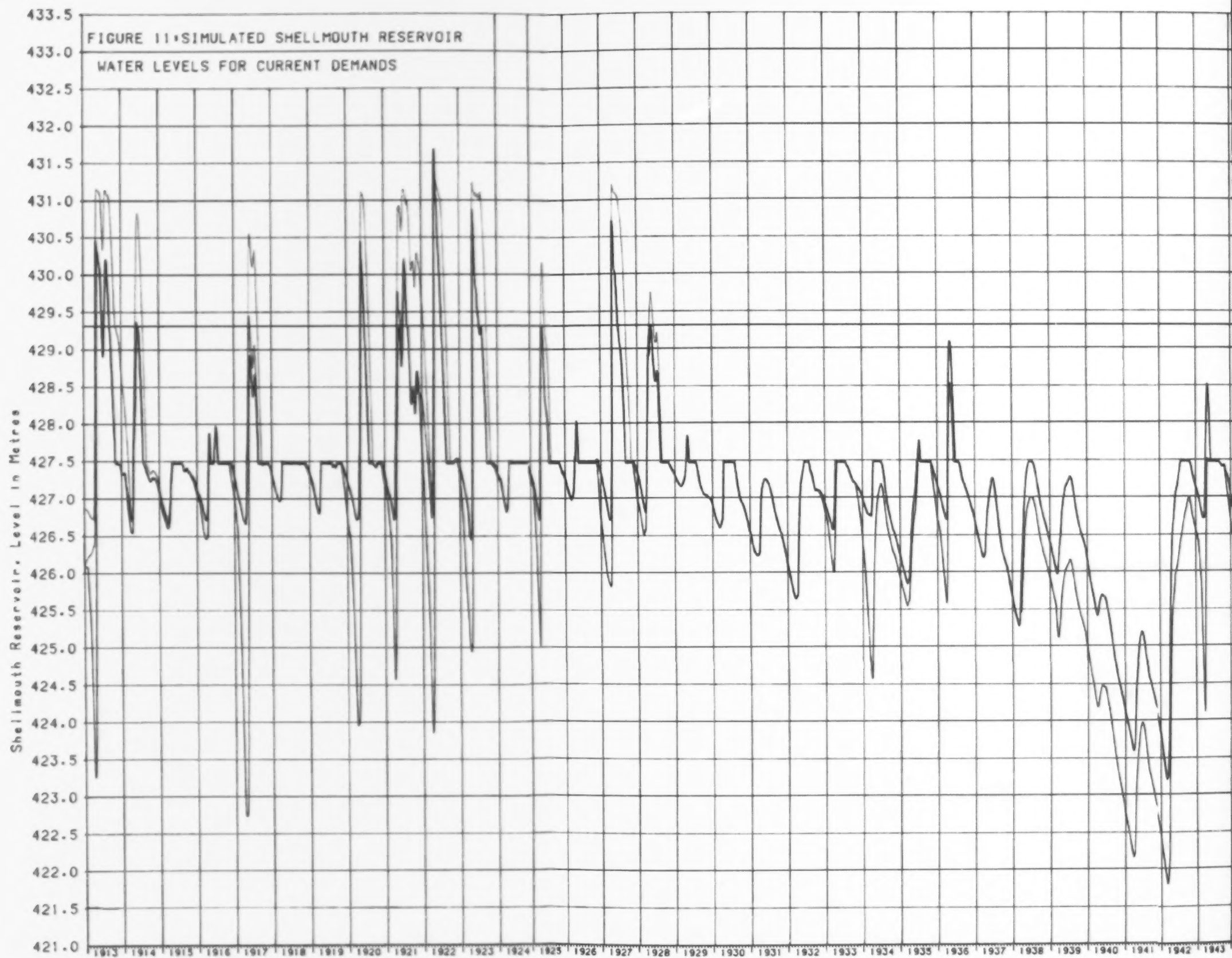
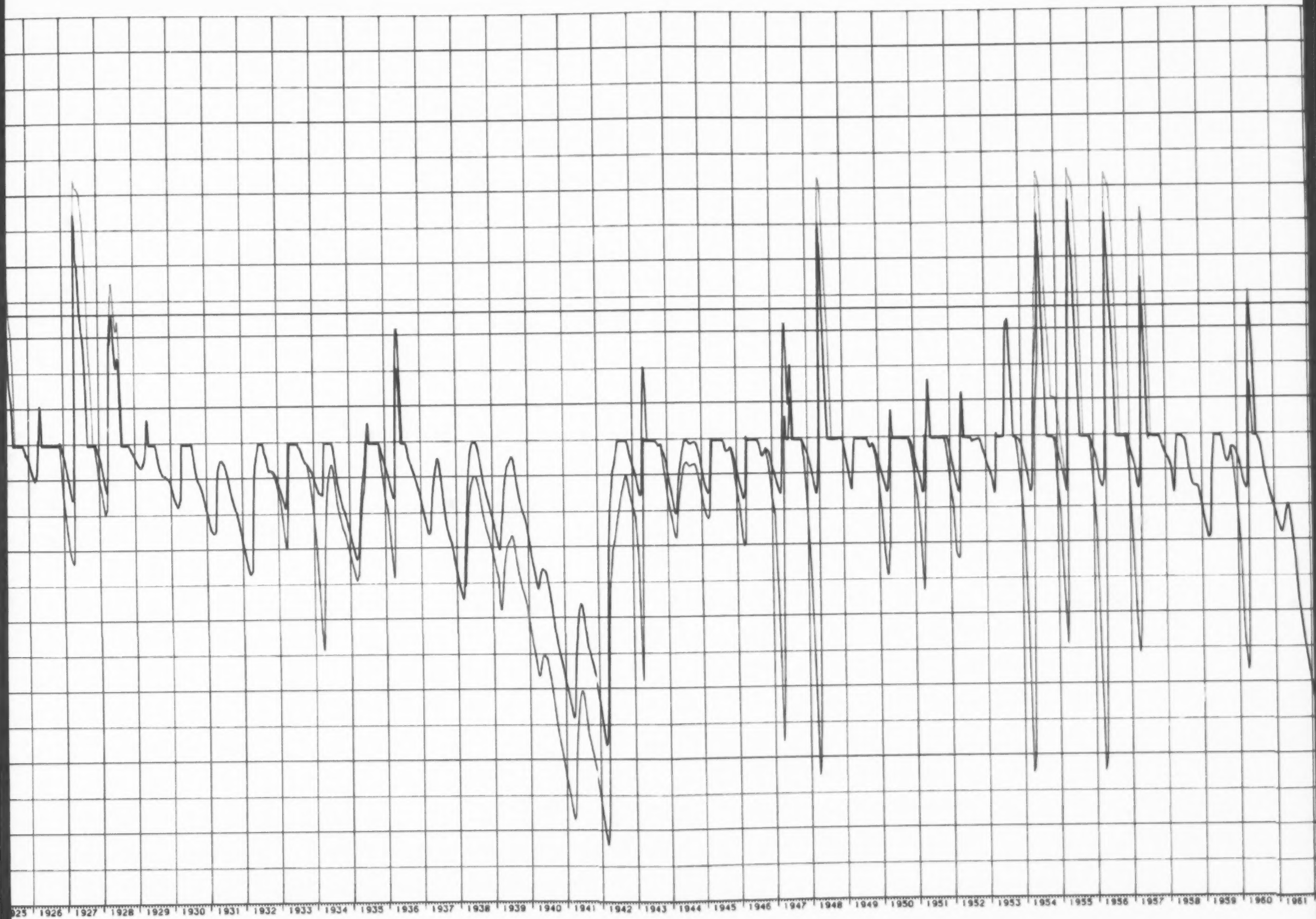


Figure 10

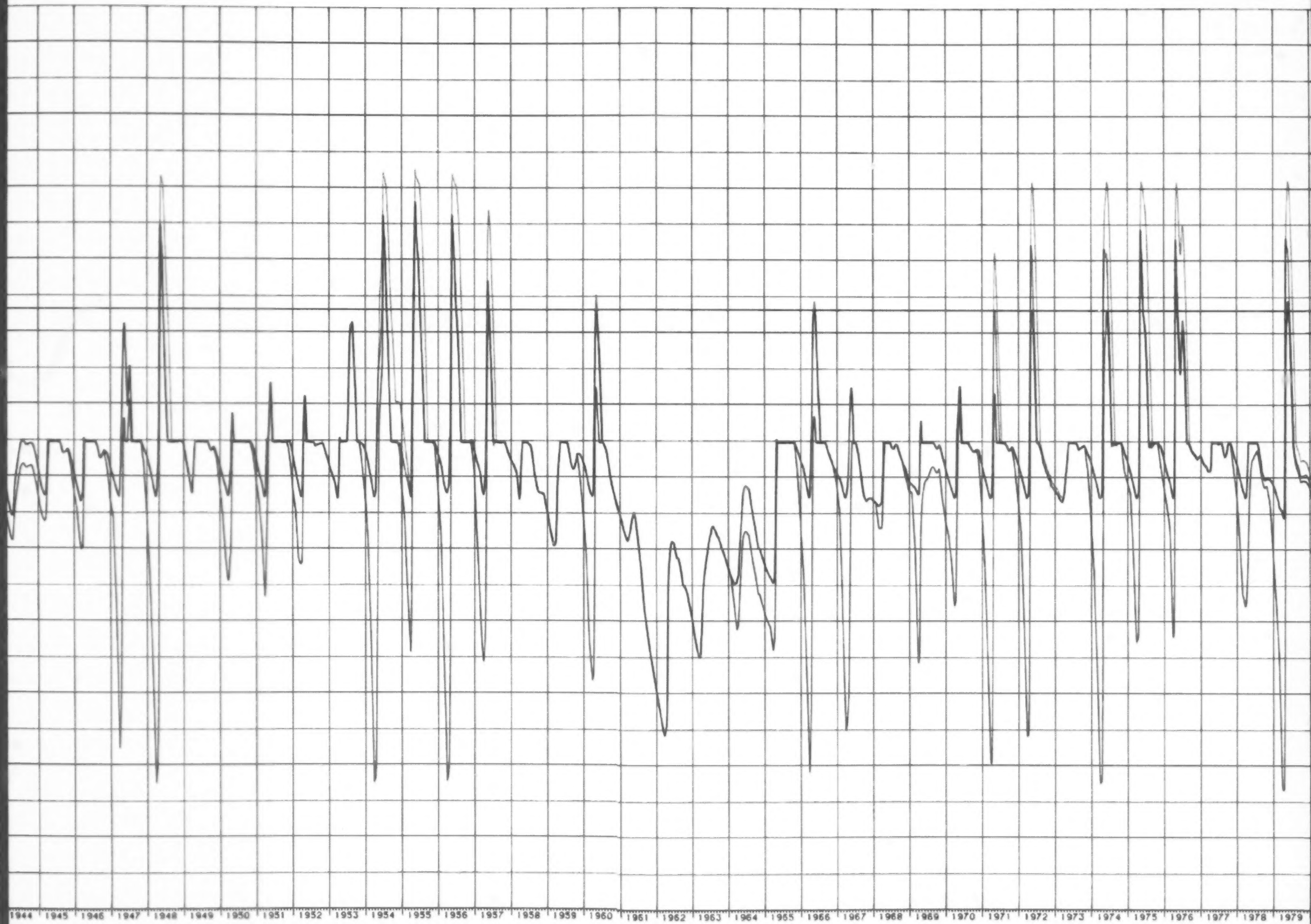






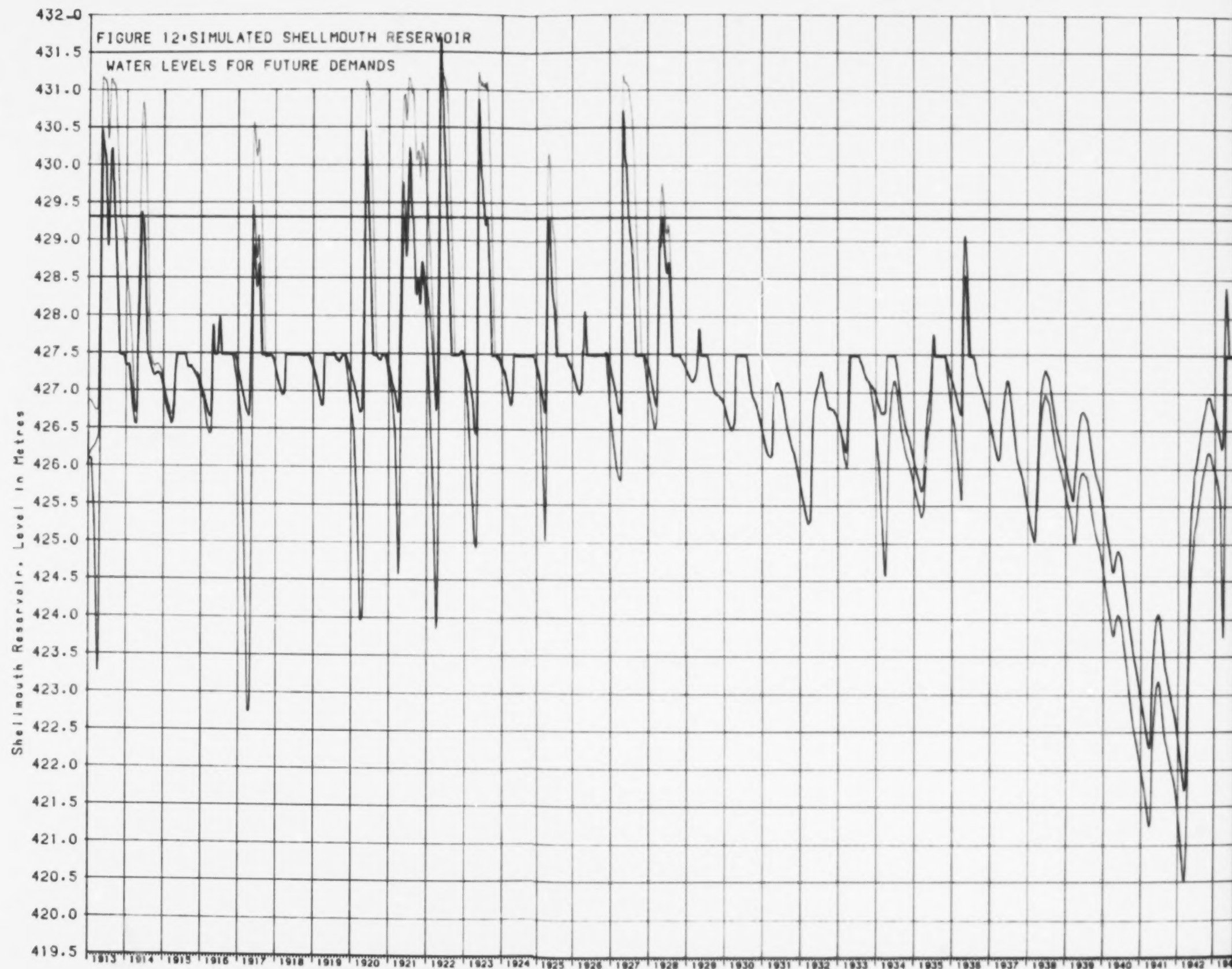
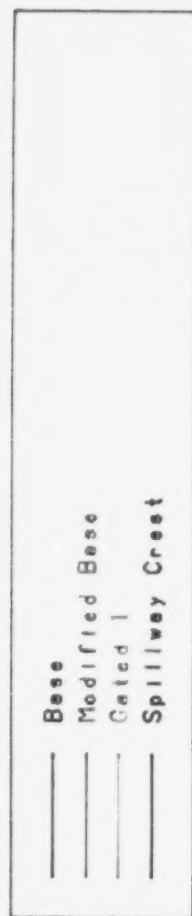




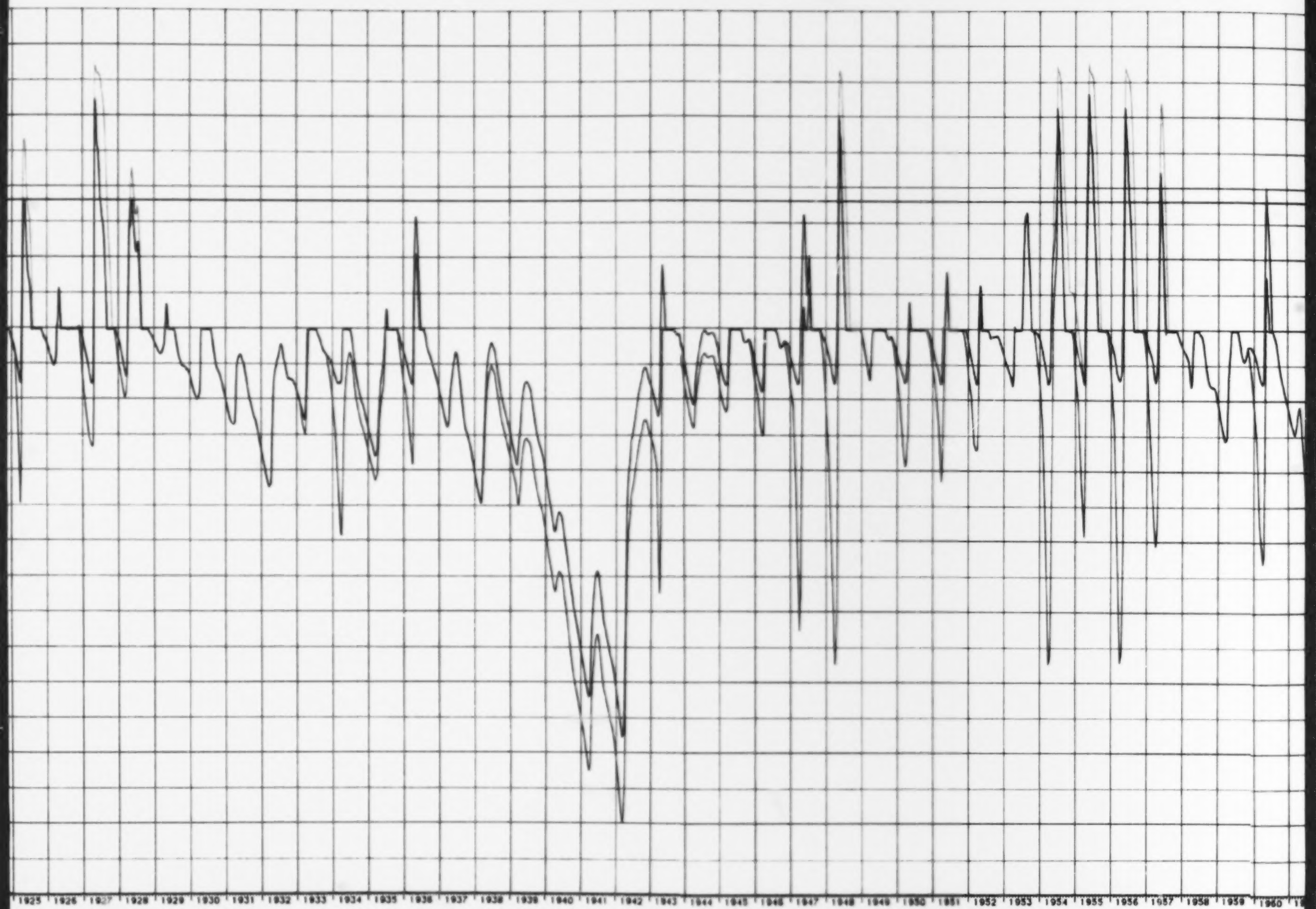




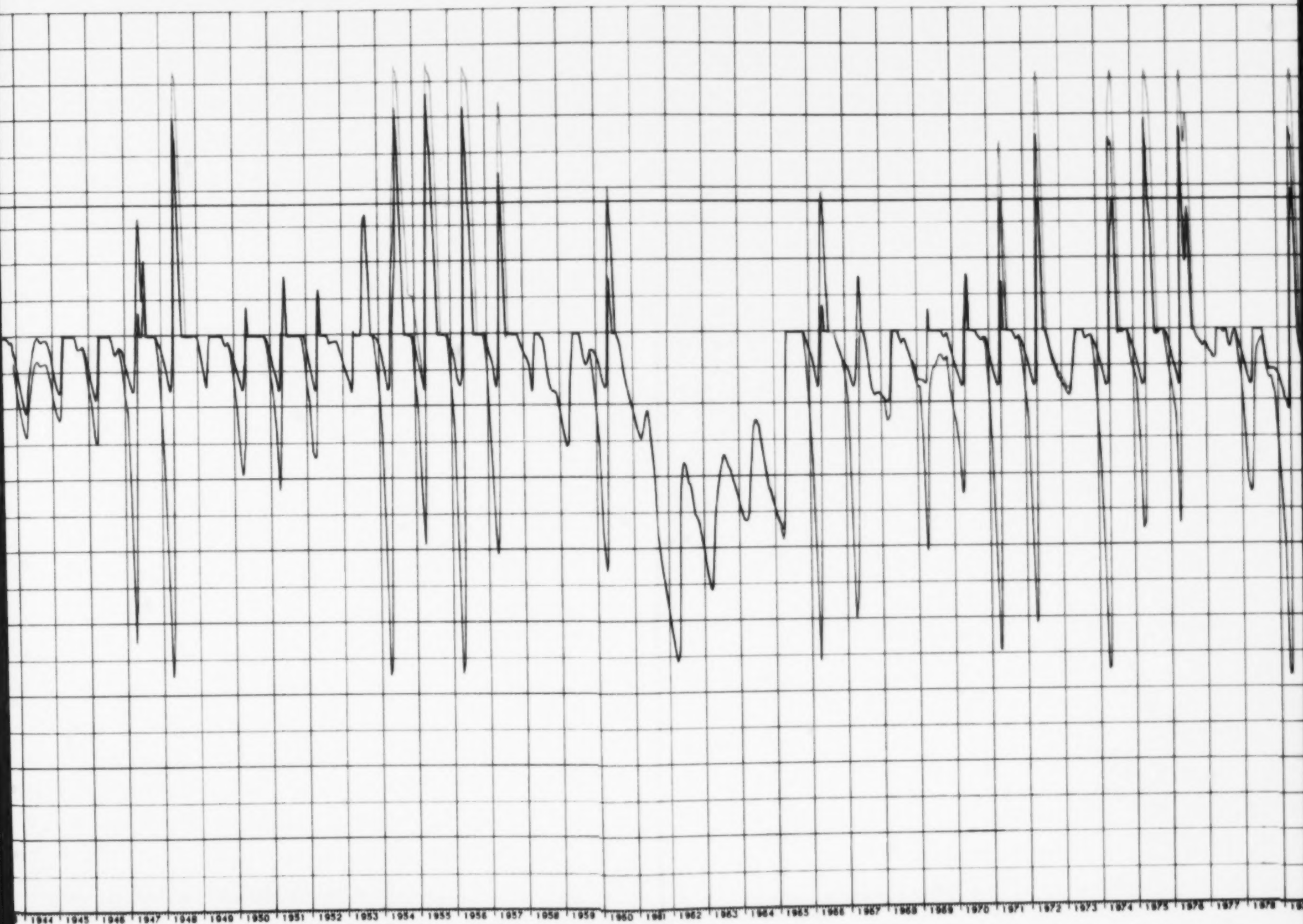
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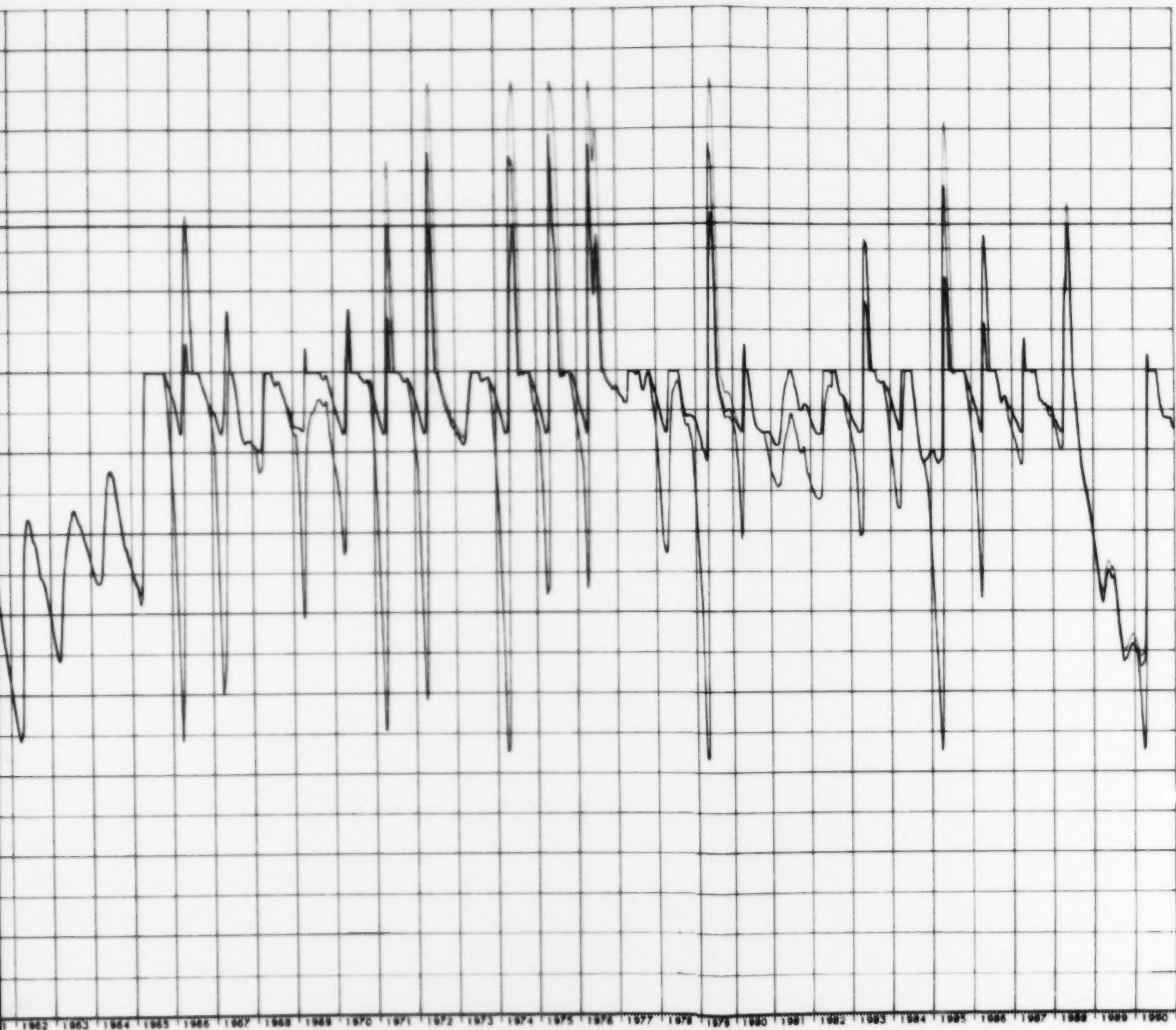




1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960



1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978





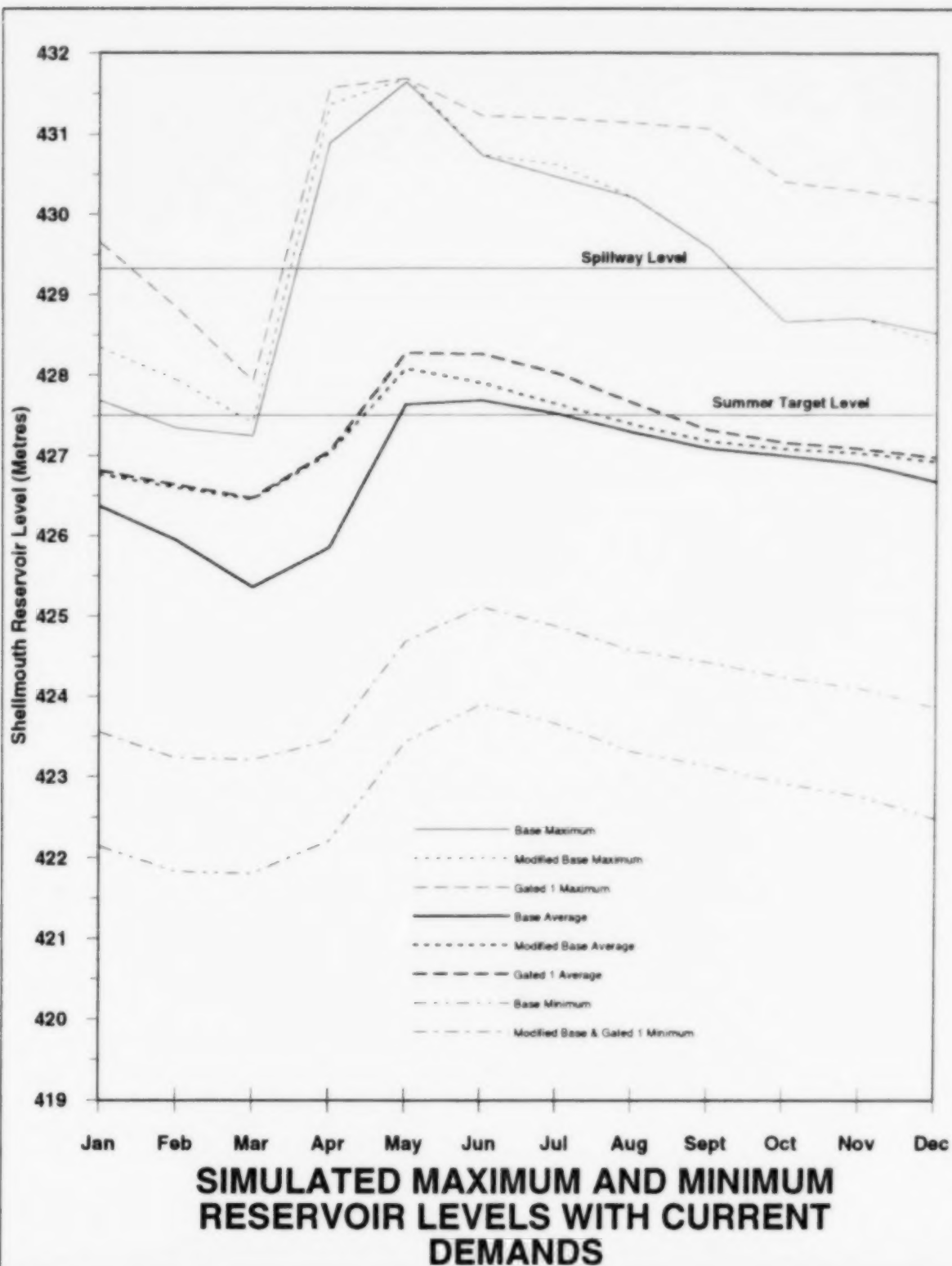


**Figure 13**

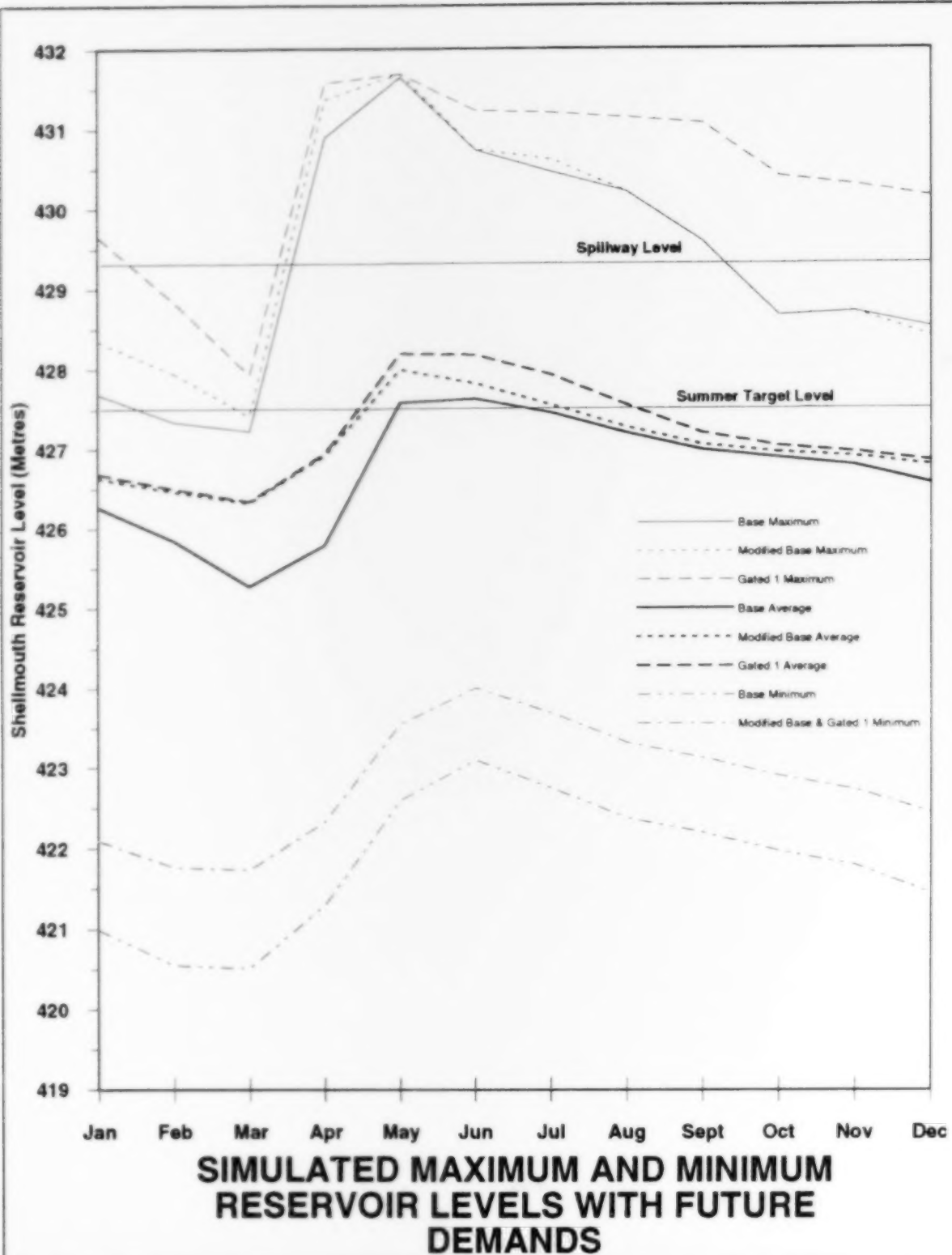
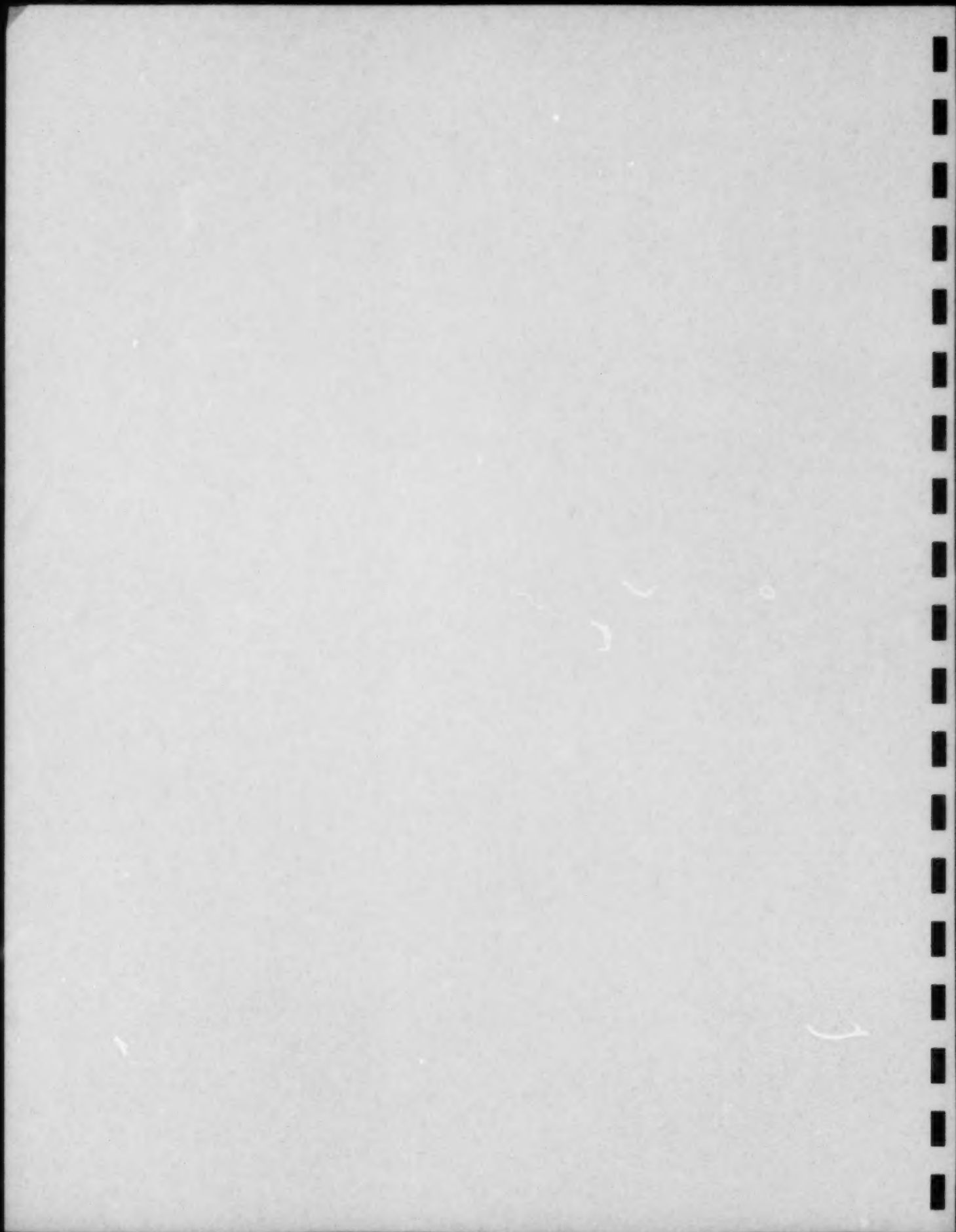


Figure 14

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**Assiniboine River Water Management Model**

## **Appendix I**





## Memorandum

Date January 14, 1992

To R. J. Bowering, P. Eng.  
Head  
Water Supply Section

From R. W. Harrison, P. Eng.  
Senior Hydrologist  
Water Supply Section

Subject **ASSINIBOINE RIVER WATER  
MANAGEMENT MODEL**

Telephone

File: 91.1  
5.5  
6.92.4.2

A water management model has been developed for the Assiniboine River system. The model enables the assessment of various operational modes of Shellmouth Reservoir to meet the river system's instream demands at Brandon, Portage La Prairie and Headingley and consumptive uses along the river. Consumptive uses and instream demands can be adjusted to indicate the impacts of present and future conditions on the river's daily flow regime and the water level regime of Shellmouth Reservoir. The Assiniboine River system is shown on Figure A-1.

Low flows on the Assiniboine River are controlled by Shellmouth Reservoir, a large multiple purpose reservoir on the river near Roblin, which was completed in 1971. The primary purpose of the reservoir was originally flood control. Today the water supply capability of the reservoir is also very important. The reservoir is lowered during the winter to provide storage for spring inflows and to provide water for municipal use and thermal cooling during the winter. In the spring, the reservoir is refilled and used to maintain desirable summer flows between the reservoir and Winnipeg. Target flows are approximately 5.66 m<sup>3</sup>/s (200 cfs) at Brandon for thermal cooling and approximately 2.83 m<sup>3</sup>/s (100 cfs) at Headingley for waste assimilation.

The model mathematically reproduces the operation of Shellmouth Reservoir and the physical river system from Shellmouth Reservoir to Headingley. The model was based on the computer simulation model derived for the 1978 Water Resources Branch Report "Simulation Study to Assess the Flood Peak Reduction Capability of Shellmouth Reservoir". The model was expanded to include for Shellmouth Reservoir probability forecasting of spring inflow volumes and winter drawdown levels, precipitation and evaporative losses, variable releases to meet downstream demands and the ability to analysis variable operating scenarios. Model inputs consist of inflows from tributaries and the Assiniboine Delta Aquifer. Withdrawals from the river, such as those due to consumptive use at Brandon and Portage la Prairie and for irrigation along the river are also included. The model operates to meet minimum target flows at Brandon, Portage la Prairie and Headingley and consumptive uses along the River. Daily water levels on Shellmouth Reservoir and flows on the river at Brandon, Portage la Prairie and Headingley are simulated for the historic period 1913 to 1990.

The model has been used to assess flows on the Assiniboine River from Shellmouth Reservoir to Headingley under various levels of water demands and operational modes of Shellmouth Reservoir. The analysis indicates Shellmouth Reservoir can meet the projected demands to the year 2040.

### Hydrologic Data

Flows on the Upper Assiniboine River date back to 1913. Therefore, the hydrologic period 1913 to 1990 was selected for the study period. This period includes the droughts of the 1930's and 1980's.



Flows were available on the Assiniboine River at Russell, Brandon and Headingley back to 1913. For periods of missing record, the flows reconstructed for the 1978 Water Resources Branch Report *"Simulation Study to Assess the Flood Peak Reduction Capability of Shellmouth Reservoir"* were used. The derivation of these flows is documented in Appendix B of the 1978 Report.

The Assiniboine River at Russell (05ME001) for the period 1913 to 1968 was used to represent the inflows to Shellmouth Reservoir. For 1969 and 1970, Shellmouth Reservoir inflows developed in the 1978 Study were used. Inflows for the period 1971 to 1990 were computed by adding the Assiniboine River at Kamsack (05MD004) routed to Shellmouth Dam, to the local inflow and the Shell River near Inglis (05MD005). The local inflow was determined by increasing the recorded flow for Stony Creek near Kamsack (05MD010) by the gross drainage area ratio. The gross drainage of Stony Creek was estimated at 461.0 square kilometres. The local drainage area between Kamsack and Shellmouth Dam, excluding the Shell River was estimated at 2904.0 square kilometres. The Assiniboine River from Kamsack to Shellmouth Dam was subdivided into two equal routing reaches. Muskingum Routing parameters of "k" and "x" equal to 1.5 and 0.10 respectively were used for each reach. The local inflow was added at the downstream end of Reach 1. The daily inflows to Shellmouth Reservoir were adjusted to present use by applying the difference between the historic and the present level of use adjustments from the November 1980 P.P.W.B Report *"Assiniboine River at Saskatchewan-Manitoba Boundary, Natural Flow"*. The monthly present uses adjustments were assumed to be uniformly distributed throughout the month before being applied to the Shellmouth Reservoir inflows.

Streamflow data for the Assiniboine River at Portage La Prairie (05MJ003) was available for the years 1923 to 1930 and 1952 to 1987. For the period 1971 to 1987 Portage Diversion near Portage La Prairie (05LL019) flows were added to the recorded flows at station 05MJ003. The Portage flows were extended back to 1913 using the Assiniboine River at Headingley (05MD001) reverse routed using a two day time of travel. The Assiniboine River at Holland (05MH005) was used from 1988 to 1990.

Present use adjustments for the Qu'Appelle and Souris Rivers were used in the model. The Qu'Appelle River monthly present use adjustments were obtained by subtracting the 1979 Saskatchewan Department of the Environment *"1979 Qu'Appelle River Study"* present use flows for the Qu'Appelle River at Welby (File QU CONV EX) for the recorded flows, with gaps filled using SNBB natural flows. Monthly present use adjustments for the Souris River were obtained by subtracting the Saskatchewan Water Corporation, Souris River at Westhope (Run J55A) mean monthly flows developed during the Rafferty Dam Study from the historic mean monthly flows. The monthly present use adjustments were assumed to be uniformly distributed throughout the month.

The most important controlled tributary in Manitoba is the Little Saskatchewan River. The Rivers Reservoir on the Little Saskatchewan generally contributes at least  $0.57 \text{ m}^3/\text{s}$  (20 cfs) to the Assiniboine River. The Reservoir came into operation in 1961. Previous studies have indicated that Rivers Reservoir operated to firm up the flows on the Assiniboine River provides little benefit with dire consequences to the Reservoir's water level regime. Therefore, Rivers Reservoir operation was excluded for the analysis.

#### **Water Demands**

Present and estimated future consumptive demands were developed for the Assiniboine River, as shown in Tables A-1 to A-3 (memorandum dated March 1, 1990 from



A. Skrepnek to J. Smithson, P. Eng. - Files 90.4.2 and 6.92.4.2). Future demands were estimated for the year 2040. Future municipal water consumption at Brandon and Portage la Prairie were projected to approximately double by 2040. Irrigation demands were also projected to double by 2040. Reach 1 includes the City of Brandon and irrigation demands between Shellmouth Reservoir and Brandon. Reach 2 includes the City of Portage la Prairie and irrigation between Brandon and Portage la Prairie. The Pembina Valley Water Cooperative Proposal to divert  $0.57 \text{ m}^3/\text{s}$  (20 cfs) from the Assiniboine River would occur in Reach 2. Reach 3 includes the full  $1.42 \text{ m}^3/\text{s}$  (50 cfs) capacity of the existing Assiniboine to La Salle River Diversion, as well as irrigation between Portage la Prairie and Winnipeg. Instream demands for thermal cooling at Brandon and fisheries and waste assimilation at Winnipeg are also noted in Tables A-1 and A-3 respectively.

### Shellmouth Reservoir Operating Rules

Shellmouth Dam and Reservoir came into full operation in 1971. Shellmouth Reservoir is multi-purposed, used for flood control, water supply, recreation and sport fisheries. The reservoir is lowered during the winter to provide storage for spring inflows and to provide water for municipal use and thermal cooling during the winter. In spring, the reservoir is refilled and used to maintain desirable summer flows between the reservoir and Winnipeg. Shellmouth Reservoir is operated to an optimum summer target level of 427.487 m (1402.5 ft) for recreation purposes. The water stored at this level is also sufficient to provide current downstream water demands. Numerous constraints are considered in the operation of the reservoir. These are primarily for flood control purposes. The existing operating rules incorporated into the reservoir segment of the Water Management Model were as follows:

1. On the first of each month from November through March, a probability forecast of the spring inflow volume to the reservoir was made. The forecast was based on the antecedent moisture conditions and the total winter precipitation. The following probability forecast equation was used (memorandum dated May 10, 1991 from A. A. Warkentin to R. J. Bowering - File 6.92.4.2):

$$\text{RUNOFF} = 3000 \cdot \text{PPT}^{2.0} \cdot 0.0167 \cdot \text{API}^{1.4}$$

|               |   |                                                                   |
|---------------|---|-------------------------------------------------------------------|
| Where: RUNOFF | = | Spring runoff volume in 1000's of acre-feet.                      |
| PPT           | = | Total winter precipitation from November 1 to March 31 in inches. |
| API           | = | Percent normal antecedent precipitation index                     |

Recorded precipitation up to the forecast date and estimated precipitation from the forecast date to March 1st was used in the forecast equation. The 90 percentile forecast was used. That is, there should be sufficient runoff in 9 out of 10 years on average to bring the reservoir back up to the summer target level.

The constant rate of release required to draw the reservoir down by March 31st to provide flood storage for the forecast spring inflow was calculated. The release rate was adjusted, if necessary, so that the flow would not drop the reservoir below the minimum winter target level or below that required to meet downstream demands. Also, the release rate was checked to ensure it would not exceed  $35.4 \text{ m}^3/\text{s}$  (1250 cfs) to prevent downstream channel icing. The maximum release rate was determined from the examination of recorded streamflow records on the Assiniboine River at Russell. In 1979, outflows were increased to the order of  $35.4 \text{ m}^3/\text{s}$  (1250 cfs) so as to drawdown the reservoir to a minimum level of 422.741 m (1386.93 feet).

2. On April 1st a 30 day inflow forecast was made. The flow rate required to attain the summer target level of 427.487 m (1402.5 ft) was determined. The calculated outflow rate was used unless constrained by limiting the April flow to a minimum of  $0.707 \text{ m}^3/\text{s}$  (25 cfs) and a maximum of  $2.83 \text{ m}^3/\text{s}$  (100 cfs). The release rate was checked to ensure the downstream demands were met and increased if required. The maximum flow of  $2.83 \text{ m}^3/\text{s}$  (100 cfs) was imposed so as to allow the downstream tributary runoff to occur and reduce downstream flooding. This procedure was repeated on the first of each month or until elevation 426.725 m (1400.0 ft) was reached.
3. On the day that the reservoir reached elevation 426.725 m (1400.0 ft), another 30 day forecast was made. At this point, the constant release that is necessary to reach the summer target level of 427.487 m (1402.5 ft) was calculated. The constant release to reach the spillway crest elevation of 429.316 m (1408.5 ft) was also calculated. The release was then determined from the following criteria using the two rates of release:
  1. If only the summer target level or lower was to be attained, the release was set at the greater of  $0.707 \text{ m}^3/\text{s}$  (25 cfs) or the downstream demand.
  2. If the summer target level was to be attained and the calculated release was less than  $42.5 \text{ m}^3/\text{s}$  (1500 cfs) the downstream channel capacity, the release was set equal to the calculated value.
  3. If the release rate of  $42.5 \text{ m}^3/\text{s}$  (1500 cfs) would allow the reservoir to attain a peak level between the summer target level of 427.487 m (1402.5 ft) and FSL of 429.316 m (1408.5 feet), the release rate was set equal to  $42.5 \text{ m}^3/\text{s}$  (1500 cfs).
  4. If the release rate calculated to attain FSL was between  $42.5 \text{ m}^3/\text{s}$  (1500) and  $70.8 \text{ m}^3/\text{s}$  (2500 cfs), the outflow was the calculated value.
  5. If the release rate was greater than  $70.8 \text{ m}^3/\text{s}$  (2500 cfs), the release rate was maintained at  $70.8 \text{ m}^3/\text{s}$  (2500 cfs) as long as possible. This would be accomplished by adjusting the conduit gates to maintain a constant outflow. When elevation 430.078 m (1411.0 ft) was reached, the conduit would be closed and the outflow would consist entirely of spillway flow. The reservoir after this time was "out of control".

When the inflow equalled the outflow on the falling limb of the runoff hydrograph, the conduit gates would be adjusted so as to maintain the steady condition of inflow equal to outflow. This condition was maintained until the inflow dropped below  $42.5 \text{ m}^3/\text{s}$  (1500 cfs). At this time, the outflow was maintained at  $42.5 \text{ m}^3/\text{s}$  (1500 cfs) until the summer target level was reached.

The summer operation consisted of simply maintaining the reservoir elevation at the summer target level until November 1st while meeting downstream demands. In the event of a summer flood, the reservoir was operated according to the preceding rules dictated by the reservoir level at the time. The existing operating rules are summarized in Table A-4.

#### **Water Management Model**

The water management model may be divided into two segments: the Assiniboine River system from Shellmouth Dam to Headingley and Shellmouth Dam and Reservoir operation.

The Shellmouth Reservoir segment handled the flood reduction capacity and the water supply potential of the reservoir. The operation constraints outlined previously were incorporated into the Reservoir model due to the reservoir's multi-use. The Assiniboine River segment adjusted flows to present or future use, determined downstream releases from Shellmouth Reservoir and routed the Shellmouth Reservoir releases along the Assiniboine River to obtain regulated daily flows at Brandon, Portage la Prairie and Headingley.

The flows along the Assiniboine River prior to 1968 approximate natural flows. Since the construction of Shellmouth Dam starting in 1968, the flows at the downstream stations have been regulated. Filling of the reservoir commenced in 1969 and full operation for flood control and water supply began in 1971. Only the recorded flows at these stations since 1971 may be considered under controlled conditions. To overcome the problem of naturalizing or adjusting to present use the flows along the Assiniboine River for the entire period of record the following procedure was adopted.

The Assiniboine River was divided into three reaches; Shellmouth Dam to Brandon, Brandon to Portage La Prairie and Portage La Prairie to Headingley. The accumulative local inflow between Shellmouth Dam and the downstream end of each reach was determined. This local inflow represented the total tributary inflow downstream of Shellmouth Dam to meet instream uses at Brandon, Portage La Prairie, and Headingley and consumptive uses along the river. The local inflows were determined by routing the historic Assiniboine River at Russell (05ME001) flows downstream to Brandon, Portage la Prairie and Headingley respectively using the Muskingum routing parameters indicated in Table A-5. As low flows were of interest, the selected routing parameters were for low flow conditions. The present use adjustments for the Qu'Appelle and Souris Rivers were included at the respective locations along the river. The routed Russell flows with the present use adjustments for the Qu'Appelle and Souris Rivers were subtracted from the historic flows at Brandon, Portage la Prairie and Headingley. The local inflows were then adjusted for the total upstream consumptive uses for present conditions or the year 2040, shown in Tables A-1 to A-3. At each of the three sites a comparison was then made between the required daily instream demand and the upstream local inflow. The daily short fall at each site was calculated. These short falls represented the required releases from Shellmouth Dam. The short falls for each site were reverse routed to Shellmouth Dam and the maximum daily value selected. These maximums were the required riparian releases from Shellmouth Dam to meet the system's instream and consumptive uses. Next, Shellmouth Reservoir inflows, adjusted to present use were routed through the reservoir using the operating rules previously outlined and the predetermined riparian releases. The computed Reservoir outflows were then routed down the Assiniboine River system using the Muskingum routing parameters shown in Table A-5 and added to the adjusted consumptive use local inflows to provide daily flows at Brandon, Portage la Prairie and Headingley under controlled conditions.

#### Shellmouth Reservoir Operational Scenarios

To meet present and estimated consumptive demands to the year 2040 three operating scenarios were examined for Shellmouth Reservoir. Instream minimum flows of  $5.66 \text{ m}^3/\text{s}$  (200 cfs) at Brandon for thermal cooling and approximately  $2.83 \text{ m}^3/\text{s}$  (100 cfs) at Headingley for waste assimilation were considered. The operating criteria outlined in the section entitled "Shellmouth Reservoir Operating Rules" were applied with slight modifications. The three scenarios are as follows:

1. **Current Operation** - This scenario models the existing operation of Shellmouth Dam and Reservoir. A probability forecast of the spring inflow volume was made with the reservoir

drawn down to a minimum winter target level of 422.763 m (1387.0 ft) for flood control purposes. This scenario is the base case.

2. **Modified Operation** - This scenario models the modified operation of Shellmouth Dam and Reservoir wherein the minimum winter target level is increased to elevation 426.725 m (1400.0 ft). The probability forecast of the spring inflow volume was included. The additional water supply storage provided is at the expense of flood control. The assumed reservoir operating rules are shown in Table A-6.
3. **Gated** - This scenario models the modified operation of Shellmouth Dam and Reservoir wherein the minimum winter target level is 426.725 m (1400.0 ft) to provide additional water supply storage. To mitigate the loss of flood storage, gates are placed on the spillway so as to raise the FSL to elevation 431.144 m (1414.5 ft). The assumed operating rules are shown in Table A-7.

## Results

The Assiniboine River water management model was used to assess the various operational scenarios of Shellmouth Dam to meet the minimum target flows at Brandon, and Headingley. As shown in Table A-8, the minimum target flows of  $5.66 \text{ m}^3/\text{s}$  (200 cfs) at Brandon for thermal cooling and  $2.83 \text{ m}^3/\text{s}$  (100 cfs) at Headingley for waste assimilation under current and projected demands for the year 2040 were met for all three operational scenarios of Shellmouth Dam. For the Modified and Gated scenarios, Portage la Prairie had a lower minimum flow. This was a result of the minimum winter target level of 426.725 m (1400.0 ft) being reached in March 1933 and only releases made to meet downstream demands. Except, for this one month the minimum flow at Portage la Prairie would have been  $5.38 \text{ m}^3/\text{s}$  (190 cfs). As shown in Table A-8, for current demands the minimum flow at Headingley is greater than the minimum target flow of  $2.83 \text{ m}^3/\text{s}$  (100 cfs). The average flows for the same locations and conditions are shown for comparison. The various operational modes make no difference in the average flow conditions. The only difference is due to increasing demands. At Brandon for the 2040 demands the long term average flow was comprised of 60 percent local inflow downstream of Shellmouth Dam and the rest from Shellmouth Reservoir outflows. Controlled releases represented about 16 percent of the total flow from Shellmouth Dam.

The minimum daily and average Shellmouth Reservoir levels for the various conditions are shown in Table A-8. As demands increase from current to projected for the year 2040, the minimum water level on Shellmouth Reservoir under current operation is expected to drop by 1.29 m (4.23 ft). If the mode of operation of Shellmouth Reservoir were changed to Modified or Gated, the minimum reservoir would be 1.40 m (4.60 ft) higher than under current conditions. Also, the minimum levels for the projected 2040 demands, would be similar to the levels expected under current operating conditions and current demands. Changing the operating scheme to Modified or Gated results in an additional 38 800 dam (31 500 acre-feet) of water storage for water supply purposes. For all three modes of operation there is very little change in the average water level. The monthly distribution of the minimum and average reservoir levels for the three operating scenarios for current and projected 2040 demands are shown on Figures A-2 and A-3 respectively.

The model has two constraints: Firstly, perfect operation of Shellmouth Dam to meet downstream demands along the Assiniboine River system was assumed. This requires an accurate projection of future releases some three weeks in advance, the travel time from Shellmouth Dam to Headingley. With the uncertainty in the weather say two weeks ahead, it

would be impossible to make precise releases for irrigation in the Portage la Prairie area. Releases would be in fact based on average conditions resulting in some wastage during periods of excess precipitation and possible shortages in periods of high evapotranspiration. The short falls could likely be made up by Rivers Reservoir operation. The second model constraint was that once a 30-day forecast was made no adjustments were made to the outflow until certain target levels were reached. In actual fact, operational forecasts are updated continuously depending on weather conditions and outflows adjusted accordingly. This could result in some loss of flood control or water supply benefits. Neither of these constraints should not significantly affect the overall results.

### Summary

The water management model has been developed and used to assess flows on the Assiniboine River from Shellmouth Reservoir to Headingley under various levels of water demands and operational modes of Shellmouth Reservoir. The analysis indicates Shellmouth Reservoir should be able to meet projected demands to the year 2040. Three operating scenarios of Shellmouth Reservoir were examined Existing, Modified and Gated. Modified and Gated operation involves raising the winter minimum water level to elevation 426.725 m (1400.0 ft). This provides additional water supply storage at the expense of flood control storage. Changing the operating scheme to Modified or Gated under projected 2040 demands results in the minimum reservoir 1.40 m (4.60 ft) higher or an additional 28 800 dam (31 500 acre-feet) of water storage for water supply purposes.



R. W. Harrison

RWH/jm

Attachment



TABLE A-1

**Current & Projected Monthly Assiniboine River Water Demand  
(Reach 1 - Shellmouth Reservoir to Brandon Generating Station)\***

| Month     | Current Year |                   |           |                   |       |                   | 2040       |                   |           |                   |       |                   |
|-----------|--------------|-------------------|-----------|-------------------|-------|-------------------|------------|-------------------|-----------|-------------------|-------|-------------------|
|           | Irrigation   |                   | Mun & Ind |                   | Total |                   | Irrigation |                   | Mun & Ind |                   | Total |                   |
|           | cfs          | m <sup>3</sup> /s | cfs       | m <sup>3</sup> /s | cfs   | m <sup>3</sup> /s | cfs        | m <sup>3</sup> /s | cfs       | m <sup>3</sup> /s | cfs   | m <sup>3</sup> /s |
| January   |              |                   | 6.3       | 0.18              | 6.3   | 0.18              |            |                   | 11.3      | 0.32              | 11.3  | 0.32              |
| February  |              |                   | 7.0       | 0.20              | 7.0   | 0.20              |            |                   | 12.1      | 0.34              | 12.1  | 0.34              |
| March     |              |                   | 6.7       | 0.19              | 6.7   | 0.19              |            |                   | 12.1      | 0.34              | 12.1  | 0.34              |
| April     |              |                   | 7.0       | 0.20              | 7.0   | 0.20              |            |                   | 12.5      | 0.35              | 12.5  | 0.35              |
| May       | 4.4          | 0.12              | 8.1       | 0.23              | 12.5  | 0.35              | 8.7        | 0.25              | 14.6      | 0.41              | 23.3  | 0.66              |
| June      | 13.2         | 0.37              | 11.6      | 0.33              | 24.8  | 0.70              | 26.1       | 0.74              | 20.9      | 0.59              | 47.0  | 1.33              |
| July      | 16.5         | 0.47              | 9.0       | 0.25              | 25.5  | 0.72              | 32.7       | 0.93              | 16.2      | 0.46              | 48.9  | 1.38              |
| August    | 13.2         | 0.37              | 9.0       | 0.25              | 22.2  | 0.63              | 26.1       | 0.74              | 16.2      | 0.46              | 42.3  | 1.20              |
| September | 4.4          | 0.12              | 7.4       | 0.21              | 11.8  | 0.33              | 8.7        | 0.25              | 13.4      | 0.38              | 22.1  | 0.63              |
| October   |              |                   | 6.7       | 0.19              | 6.7   | 0.19              |            |                   | 12.1      | 0.34              | 12.1  | 0.34              |
| November  |              |                   | 7.0       | 0.20              | 7.0   | 0.20              |            |                   | 12.5      | 0.35              | 12.5  | 0.35              |
| December  |              |                   | 6.3       | 0.18              | 6.3   | 0.18              |            |                   | 11.3      | 0.32              | 11.3  | 0.32              |

\*Additional non-consumptive use at the Brandon Thermal Plant is licensed at 200 cfs (5.66 m<sup>3</sup>/s)



TABLE A-2

**Current & Projected Monthly Assiniboine River Water Demand  
(Reach 2 - Brandon to Portage la Prairie)**

| Month   | Current Year |                   |           |                   |       |                   | 2040       |                   |           |                   |       |                   |
|---------|--------------|-------------------|-----------|-------------------|-------|-------------------|------------|-------------------|-----------|-------------------|-------|-------------------|
|         | Irrigation   |                   | Mun & Ind |                   | Total |                   | Irrigation |                   | Mun & Ind |                   | Total |                   |
|         | cfs          | m <sup>3</sup> /s | cfs       | m <sup>3</sup> /s | cfs   | m <sup>3</sup> /s | cfs        | m <sup>3</sup> /s | cfs       | m <sup>3</sup> /s | cfs   | m <sup>3</sup> /s |
| January |              |                   | 3.0       | 0.08              | 3.0   | 0.08              |            |                   | 6.3       | 0.18              | 6.3   | 0.18              |
| Feb.    |              |                   | 2.9       | 0.08              | 2.9   | 0.08              |            |                   | 5.9       | 0.17              | 5.9   | 0.17              |
| March   |              |                   | 3.0       | 0.08              | 3.0   | 0.08              |            |                   | 6.3       | 0.18              | 6.3   | 0.18              |
| April   |              |                   | 3.1       | 0.09              | 3.1   | 0.09              |            |                   | 6.5       | 0.18              | 6.5   | 0.18              |
| May     | 15.4         | 0.44              | 3.7       | 0.10              | 19.1  | 0.54              | 30.5       | 0.86              | 7.9       | 0.22              | 38.4  | 1.09              |
| June    | 46.2         | 1.31              | 3.5       | 0.10              | 49.7  | 1.41              | 91.5       | 2.59              | 7.3       | 0.21              | 98.8  | 2.80              |
| July    | 57.8         | 1.64              | 3.6       | 0.10              | 61.4  | 1.74              | 114.4      | 3.24              | 7.1       | 0.20              | 121.5 | 3.44              |
| August  | 46.2         | 1.31              | 3.6       | 0.10              | 49.8  | 1.41              | 91.5       | 2.59              | 7.1       | 0.20              | 98.6  | 2.79              |
| Sept.   | 15.4         | 0.44              | 3.3       | 0.09              | 18.7  | 0.53              | 30.5       | 0.86              | 6.9       | 0.20              | 37.4  | 1.06              |
| October |              |                   | 3.6       | 0.10              | 3.6   | 0.10              |            |                   | 7.1       | 0.20              | 7.1   | 0.20              |
| Nov.    |              |                   | 2.9       | 0.08              | 2.9   | 0.08              |            |                   | 6.1       | 0.17              | 6.1   | 0.17              |
| Dec.    |              |                   | 2.6       | 0.07              | 2.6   | 0.07              |            |                   | 5.5       | 0.16              | 5.5   | 0.16              |

TABLE A-3

**Current & Projected Monthly Assiniboine River Water Demand  
(Reach 3 - Portage la Prairie to Winnipeg)\***

| Month    | Current Year |                   |               |                   |       |                   | 2040       |                   |           |                   |       |                   |
|----------|--------------|-------------------|---------------|-------------------|-------|-------------------|------------|-------------------|-----------|-------------------|-------|-------------------|
|          | Irrigation   |                   | Assin-LaSalle |                   | Total |                   | Irrigation |                   | Mun & Ind |                   | Total |                   |
|          | cfs          | m <sup>3</sup> /s | cfs           | m <sup>3</sup> /s | cfs   | m <sup>3</sup> /s | cfs        | m <sup>3</sup> /s | cfs       | m <sup>3</sup> /s | cfs   | m <sup>3</sup> /s |
| January  |              |                   | 10            | 0.28              | 10    | 0.28              |            |                   | 10        | 0.28              | 10.0  | 0.28              |
| February |              |                   | 10            | 0.28              | 10    | 0.28              |            |                   | 10        | 0.28              | 10.0  | 0.28              |
| March    |              |                   | 10            | 0.28              | 10    | 0.28              |            |                   | 10        | 0.28              | 10.0  | 0.28              |
| April    |              |                   | 10            | 0.28              | 10    | 0.28              |            |                   | 10        | 0.28              | 10.0  | 0.28              |
| May      | 11.2         | 0.32              | 50            | 1.42              | 61.2  | 1.73              | 22.2       | 0.63              | 50        | 1.42              | 72.2  | 2.04              |
| June     | 33.6         | 0.95              | 50            | 1.42              | 83.6  | 2.37              | 66.5       | 1.88              | 50        | 1.42              | 116.5 | 3.30              |
| July     | 42.0         | 1.19              | 50            | 1.42              | 92.0  | 2.61              | 83.2       | 2.36              | 50        | 1.42              | 133.2 | 3.77              |
| August   | 33.6         | 0.95              | 50            | 1.42              | 83.6  | 2.37              | 66.5       | 1.88              | 50        | 1.42              | 116.5 | 3.30              |
| Sept.    | 11.2         | 0.32              | 50            | 1.42              | 61.2  | 1.73              | 22.2       | 0.63              | 50        | 1.42              | 72.2  | 2.04              |
| October  |              |                   | 50            | 1.42              | 50.0  | 1.42              |            |                   | 50        | 1.42              | 50.0  | 1.42              |
| November |              |                   | 10            | 0.28              | 10.0  | 0.28              |            |                   | 10        | 0.28              | 10.0  | 0.28              |
| December |              |                   | 10            | 0.28              | 10.0  | 0.28              |            |                   | 10        | 0.28              | 10.0  | 0.28              |

\*Additionally, 100 cfs (2.83 m<sup>3</sup>/s) is normally made available for instream purposes at Headingley - includes City of Winnipeg.

TABLE A-4

## SIMPLIFIED GUIDELINES FOR OPERATION OF SHELLMOUTH RESERVOIR

Date or ConditionExisting Operation

|                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|--------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| November 1st                               | Forecast winter inflows - set outflow to attain minimum winter target level elevation of 422.763m by March 31st                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| December 1st                               | Update forecast and adjust outflow                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| January 1st                                | Update forecast and adjust outflow                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| February 1st                               | Update forecast and adjust outflow                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| March 1st                                  | Update forecast and adjust outflow                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| April 1st                                  | Predict next 30 days inflow and set the constant release required to attain peak elevation of 427.487m under the constraint<br>$0.707 \text{ m}^3/\text{s} \leq \text{outflow} \leq 2.83 \text{ m}^3/\text{s}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Elevation 426.725m<br>reached on reservoir | Make 30-day prediction of inflow and determine the constant releases<br>$Q_{\text{cons}}$ such that peak elevation of 427.487m is attained<br>and $Q_{\text{pr}}$ such that peak elevation of 429.316m is attained<br>A. If $Q_{\text{cons}} \leq 0.707 \text{ m}^3/\text{s}$ , set outflow = $0.707 \text{ m}^3/\text{s}$<br>B. If $0.707 \text{ m}^3/\text{s} < Q_{\text{cons}} < 42.5 \text{ m}^3/\text{s}$ , set outflow = $Q_{\text{cons}}$<br>C. If $Q_{\text{pr}} \leq 42.5 \text{ m}^3/\text{s} < Q_{\text{cons}}$ , set outflow = $42.5 \text{ m}^3/\text{s}$<br>D. If $42.5 \text{ m}^3/\text{s} < Q_{\text{pr}} < 70.8 \text{ m}^3/\text{s}$ , set outflow = $Q_{\text{pr}}$<br>E. If $70.8 \text{ m}^3/\text{s} \leq Q_{\text{pr}}$ , set outflow = $70.8 \text{ m}^3/\text{s}$ and hold as long as possible |
| Falling limb<br>of hydrograph              | *Set Outflow = Inflow until Inflow $\leq 42.5 \text{ m}^3/\text{s}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Inflow $\leq 42.5 \text{ m}^3/\text{s}$    | *Set Outflow = $42.5 \text{ m}^3/\text{s}$ until reservoir drops to elevation 427.487m                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Elevation 427.487m                         | *Set Outflow = Inflow maintaining elevation 427.487m until November 1st (summer operation)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

NOTE: Any of the phases marked with an asterisk (\*) may be by-passed if exceedingly high or low flow conditions are encountered.  
Also outflow is checked to ensure that downstream demands are met.

**TABLE A-5****ASSINIBOINE RIVER MUSKINGUM ROUTING PARAMETERS**

| Reach                   | K    | X    |
|-------------------------|------|------|
| Shellmouth to Russell   | 2.00 | 0.20 |
| Russell to St. Lazare   | 2.50 | 0.20 |
| St. Lazare to Miniota   | 2.50 | 0.20 |
| Miniota to Virden       | 2.50 | 0.10 |
| Virden to Griswold      | 2.00 | 0.10 |
| Griswold to Brandon     | 2.00 | 0.10 |
| Brandon to Souris River | 1.00 | 0.10 |
| Souris River to Holland | 1.00 | 0.10 |
| Holland to Portage      | 3.50 | 0.10 |
| Portage to Headingley   | 2.00 | 0.20 |

TABLE A-6

## SIMPLIFIED GUIDELINES FOR OPERATION OF SHELLMOUTH RESERVOIR

| <u>Date or Condition</u>                | <u>Modified Operation</u>                                                                                           |
|-----------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| November 1st                            | Forecast winter inflows - set outflow to attain minimum winter target level elevation of 422.725m by March 31st     |
| December 1st                            | Update forecast and adjust outflow                                                                                  |
| January 1st                             | Update forecast and adjust outflow                                                                                  |
| February 1st                            | Update forecast and adjust outflow                                                                                  |
| March 1st                               | Update forecast and adjust outflow                                                                                  |
| April 1st                               | Make 30-day prediction of inflow and determine the constant releases                                                |
| Elevation 426.725m                      | Qcons such that peak elevation of 427.487m is attained                                                              |
| reservoir                               | and Qpr such that peak elevation of 429.316m is attained                                                            |
|                                         | A. If $Qcons \leq 0.707 \text{ m}^3/\text{s}$ , set outflow = $0.707 \text{ m}^3/\text{s}$                          |
|                                         | B. If $0.707 \text{ m}^3/\text{s} < Qcons < 42.5 \text{ m}^3/\text{s}$ , set outflow = Qcons                        |
|                                         | C. If $Qpr \leq 42.5 \text{ m}^3/\text{s} < Qcons$ , set outflow = $42.5 \text{ m}^3/\text{s}$                      |
|                                         | D. If $42.5 \text{ m}^3/\text{s} < Qpr < 70.8 \text{ m}^3/\text{s}$ , set outflow = Qpr                             |
|                                         | E. If $70.8 \text{ m}^3/\text{s} \leq Qpr$ , set outflow = $70.8 \text{ m}^3/\text{s}$ and hold as long as possible |
| Falling limb<br>of hydrograph           | *Set Outflow = Inflow until Inflow $\leq 42.5 \text{ m}^3/\text{s}$                                                 |
| Inflow $\leq 42.5 \text{ m}^3/\text{s}$ | *Set Outflow = $42.5 \text{ m}^3/\text{s}$ until reservoir drops to elevation 427.487m                              |
| Elevation 427.487m                      | *Set Outflow = Inflow maintaining elevation 427.487m until November 1st (summer operation)                          |

NOTE: Any of the phases marked with an asterisk (\*) may be by-passed if exceedingly high or low flow conditions are encountered.  
Also outflow is checked to ensure that downstream demands are met.

TABLE A-7

## SIMPLIFIED GUIDELINES FOR OPERATION OF SHELLMOUTH RESERVOIR

Date or ConditionGated Operation

November 1st  
 December 1st  
 January 1st  
 February 1st  
 March 1st

Forecast winter inflows - set outflow to attain minimum winter target level elevation of 422.725m by March 31st  
 Update forecast and adjust outflow  
 Update forecast and adjust outflow  
 Update forecast and adjust outflow  
 Update forecast and adjust outflow

April 1st  
 Elevation 426.725m  
 reservoir

Make 30-day prediction of inflow and determine the constant releases  
 Qcons such that peak elevation of 427.487m is attained  
 and Qpr such that peak elevation of 431.144m is attained

- |    |                                                                                      |                                                            |
|----|--------------------------------------------------------------------------------------|------------------------------------------------------------|
| A. | If $Q_{cons} \leq 0.707 \text{ m}^3/\text{s}$ , set outflow                          | = $0.707 \text{ m}^3/\text{s}$                             |
| B. | If $0.707 \text{ m}^3/\text{s} < Q_{cons} < 42.5 \text{ m}^3/\text{s}$ , set outflow | = $Q_{cons}$                                               |
| C. | If $Q_{pr} \leq 42.5 \text{ m}^3/\text{s} < Q_{cons}$ , set outflow                  | = $42.5 \text{ m}^3/\text{s}$                              |
| D. | If $42.5 \text{ m}^3/\text{s} < Q_{pr} < 70.8 \text{ m}^3/\text{s}$ , set outflow    | = $Q_{pr}$                                                 |
| E. | If $70.8 \text{ m}^3/\text{s} \leq Q_{pr}$ , set outflow                             | = $70.8 \text{ m}^3/\text{s}$ and hold as long as possible |

Falling limb  
 of hydrograph

\*Set Outflow = Inflow until Inflow  $\leq 42.5 \text{ m}^3/\text{s}$

Inflow  $\leq 42.5 \text{ m}^3/\text{s}$

\*Set Outflow =  $42.5 \text{ m}^3/\text{s}$  until reservoir drops to elevation 427.487m

Elevation 427.487m

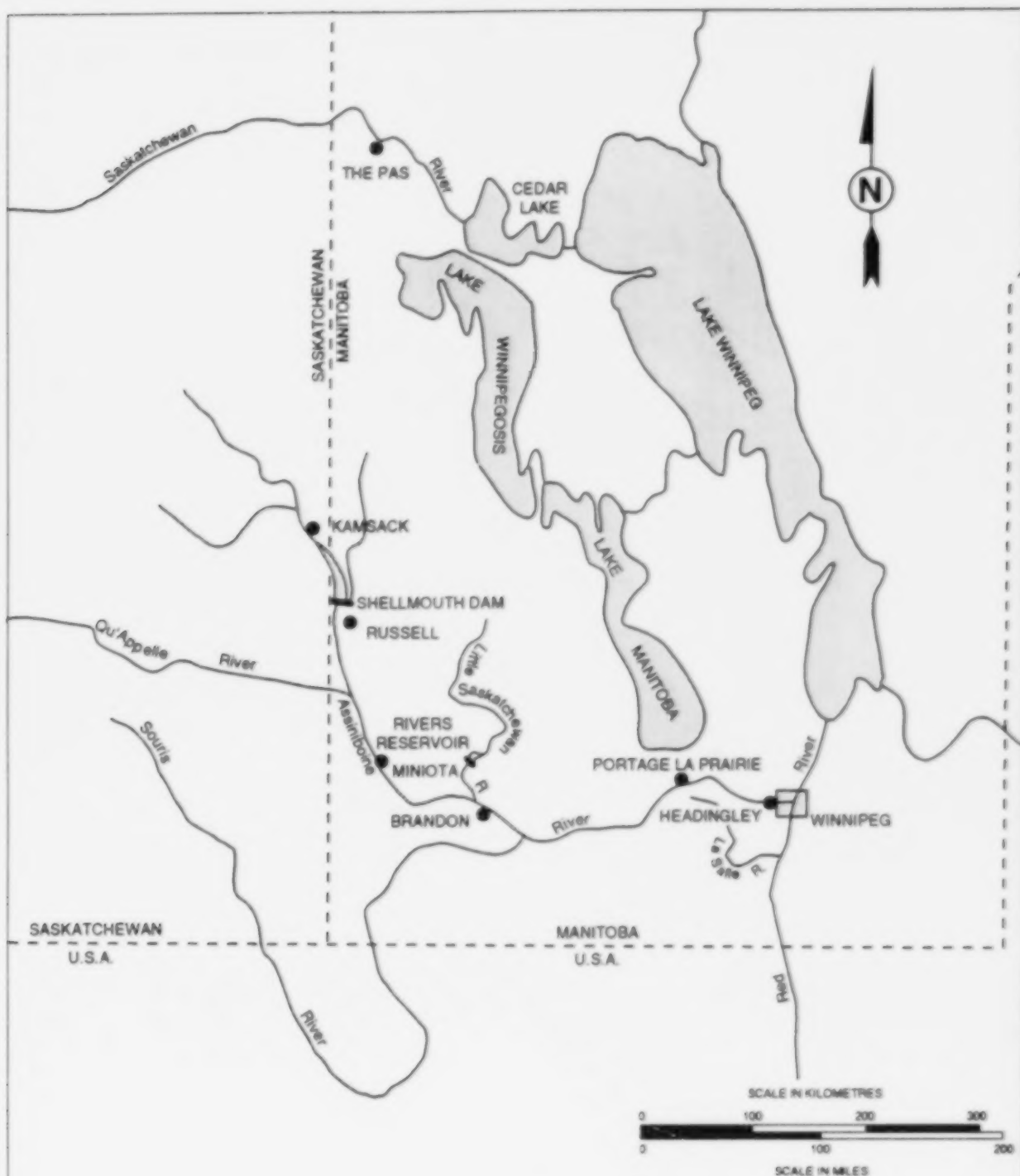
\*Set Outflow = Inflow maintaining elevation 427.487m until November 1st (summer operation)

NOTE: Any of the phases marked with an asterisk (\*) may be by-passed if exceedingly high or low flow conditions are encountered.  
 Also outflow is checked to ensure that downstream demands are met.



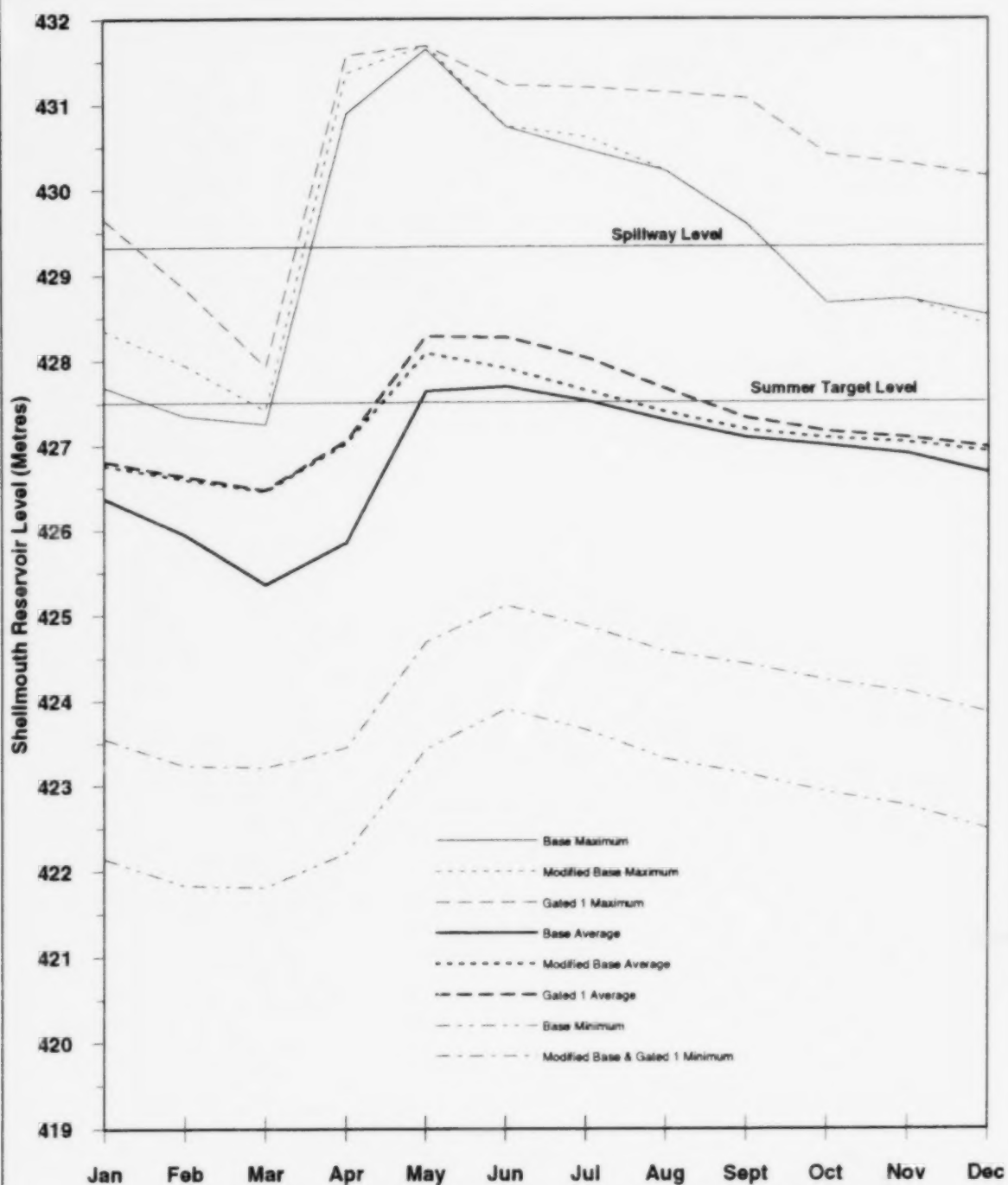
**TABLE A-8**  
**WATER SUPPLY ANALYSIS RESULTS**

|                      | Current Demands   |         |                   |         |                   |         | 2040 Demands      |         |                   |         |                   |         |
|----------------------|-------------------|---------|-------------------|---------|-------------------|---------|-------------------|---------|-------------------|---------|-------------------|---------|
|                      | Current           |         | Modified          |         | Gated             |         | Current           |         | Modified          |         | Gated             |         |
| Brandon              | m <sup>3</sup> /s | cfs     | m <sup>3</sup> /s | cfs     | m <sup>3</sup> /s | cfs     | m <sup>3</sup> /s | cfs     | m <sup>3</sup> /s | cfs     | m <sup>3</sup> /s | cfs     |
| Minimum monthly flow | 5.66              | 200     | 5.66              | 200     | 5.66              | 200     | 5.66              | 200     | 5.66              | 200     | 5.66              | 200     |
| Average flow         | 30.0              | 1059    | 30.0              | 1059    | 30.0              | 1059    | 29.7              | 1049    | 29.7              | 1049    | 29.7              | 1049    |
| Portage              | m <sup>3</sup> /s | cfs     | m <sup>3</sup> /s | cfs     | m <sup>3</sup> /s | cfs     | m <sup>3</sup> /s | cfs     | m <sup>3</sup> /s | cfs     | m <sup>3</sup> /s | cfs     |
| Minimum monthly flow | 5.38              | 190     | 4.25              | 150     | 4.25              | 140     | 4.81              | 170     | 3.96              | 140     | 3.96              | 140     |
| Average flow         | 47.2              | 1667    | 47.2              | 1666    | 47.2              | 1667    | 45.8              | 1618    | 45.8              | 1618    | 45.5              | 1618    |
| Headingley           | m <sup>3</sup> /s | cfs     | m <sup>3</sup> /s | cfs     | m <sup>3</sup> /s | cfs     | m <sup>3</sup> /s | cfs     | c <sup>3</sup> /s | cfs     | m <sup>3</sup> /s | cfs     |
| Minimum monthly flow | 3.54              | 125     | 3.54              | 125     | 3.54              | 125     | 2.83              | 100     | 2.83              | 100     | 2.83              | 100     |
| Average flow         | 43.0              | 1520    | 42.8              | 1510    | 43.0              | 1520    | 41.4              | 1462    | 41.0              | 1449    | 41.1              | 1452    |
| Shellmouth Reservoir | m                 | ft      | m                 | ft      | m                 | ft      | m                 | ft      | m                 | ft      | m                 | ft      |
| Minimum daily level  | 421.809           | 1383.87 | 423.211           | 1388.47 | 423.211           | 1388.47 | 420.519           | 1379.64 | 421.736           | 1383.63 | 421.736           | 1383.63 |
| Average level        | 426.774           | 1400.16 | 427.170           | 1401.46 | 427.310           | 1401.92 | 426.686           | 1399.87 | 427.054           | 1401.08 | 427.195           | 1401.54 |



## ASSINIBOINE RIVER LOCATION PLAN

Figure A-1



**SIMULATED MAXIMUM AND MINIMUM  
RESERVOIR LEVELS WITH CURRENT  
DEMANDS**

*Figure A-2*

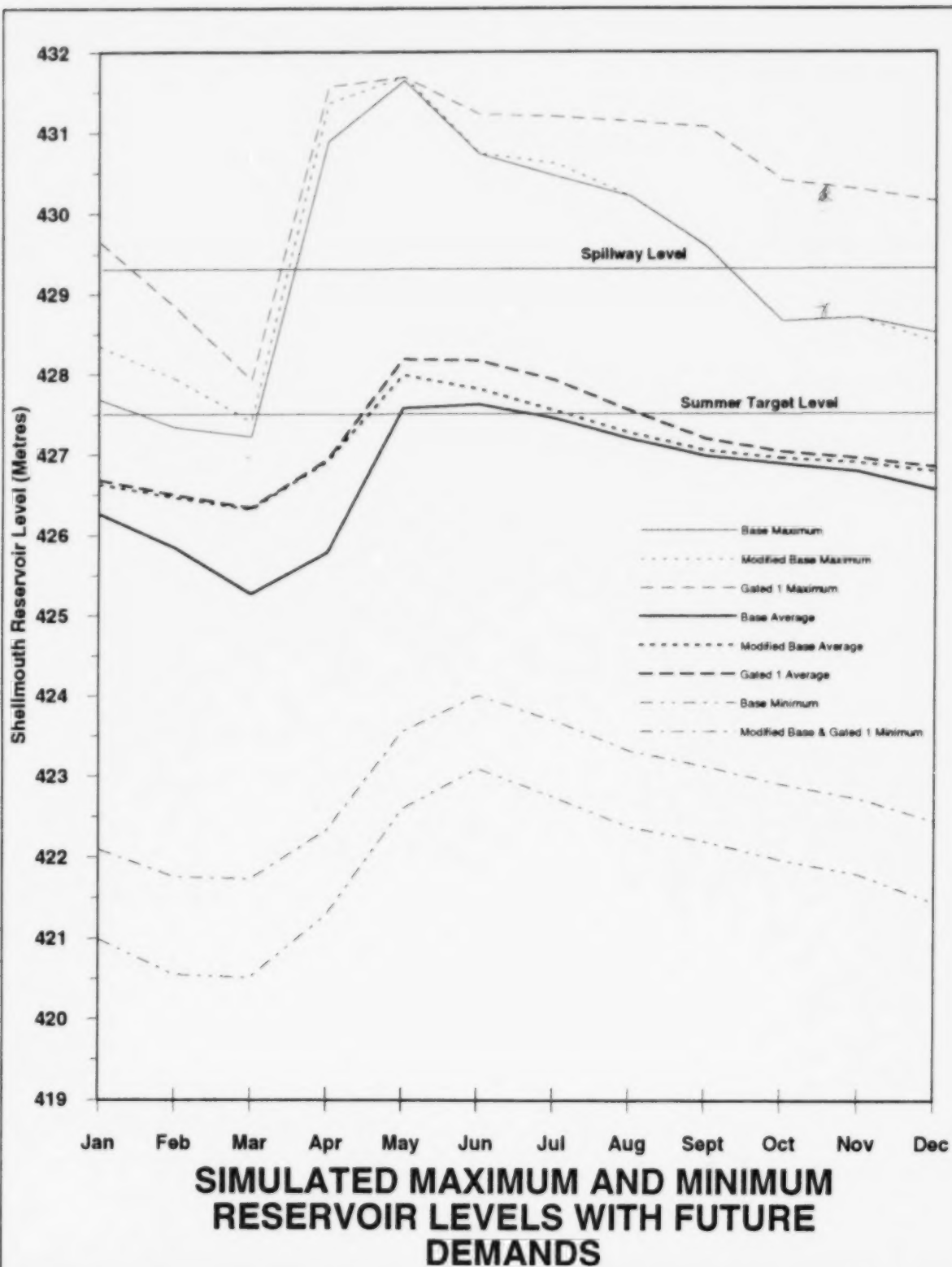
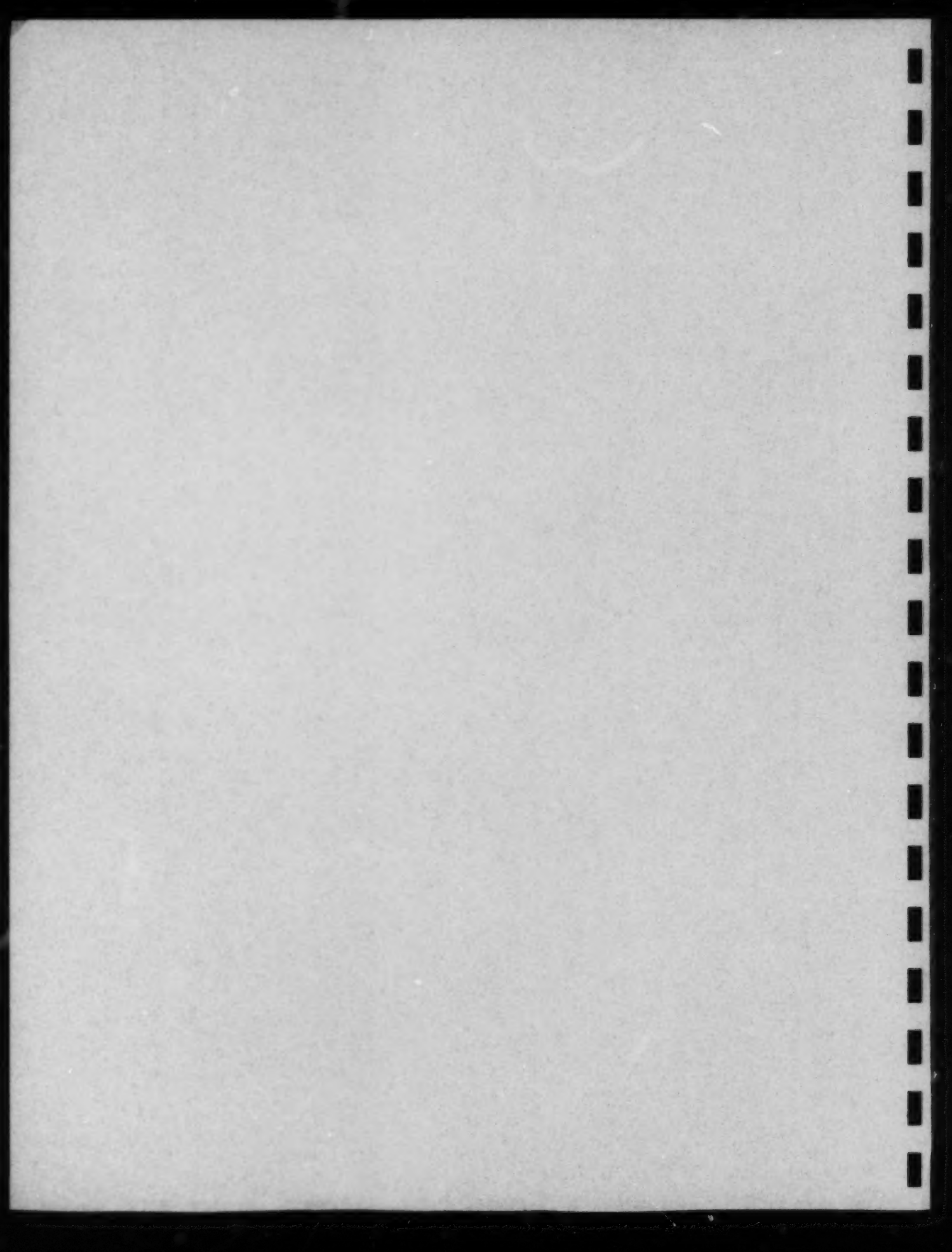


**Figure A-3**

## **Appendix II**

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### **Preliminary Study of Spillway Control Gates**





**SHELLMOUTH RESERVOIR STUDY**

**PRELIMINARY STUDY**

**OF**

**SPILLWAY CONTROL GATES**

Design Division

January, 1992



**SHELLMOUTH RESERVOIR STUDY**

**PRELIMINARY STUDY**

**OF**

**SPILLWAY CONTROL GATES**

Design Division  
Regina, Saskatchewan  
January, 1992

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## Synopsis

Shellmouth dam is located on the Assiniboine River just north of Shellmouth, Manitoba, near the Manitoba-Saskatchewan border. Operations of the dam and reservoir have been investigated in order to determine the potential of the reservoir to provide an increase in water supply potential to benefit the area downstream. The Phase I report concluded that two operating scenarios warranted further study. One option would modify the reservoir operating rules by changing the winter target pool elevation. The other option, in addition to the modified winter target pool elevation, would entail the incorporation of gates to the existing spillway structure to control flood flows.

As part of the Phase II investigations, Manitoba Regional Division requested that Design Division investigate the technical feasibility and costs of incorporating gates into the existing spillway control structure. This report details the investigations of four alternative gating options : radial gates, vertical lift gates, rubber dams and drop leaf gates. All the investigated options are technically feasible, and would provide some form of control of reservoir level and discharge during the passage of flood flows. The estimated cost of each alternative includes 30% contingencies and excludes engineering costs.

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## 1. Introduction

Shellmouth dam is located on the Assiniboine River just north of Shellmouth, Manitoba, near the Manitoba-Saskatchewan border. The Lake of the Prairies reservoir extends upstream to the Saskatchewan border. The project was constructed in the early 1960's, and was originally developed primarily for flood attenuation. The lake has since developed into a valuable water supply and recreational resource for Manitoba.

The dam is still operated as a flood control structure, with the reservoir drawn down during the winter in anticipation of spring inflow. During the summer, releases provide a water supply for downstream communities. However, due to recent droughts in the area, several agricultural regions and urban areas have expressed an interest in increasing the water supply potential of the dam to benefit the area downstream. As a result, Manitoba Natural Resources and PFRA have jointly investigated methods of increasing the water supply potential of Shellmouth dam while attempting to maintain its effectiveness in controlling floods. These Phase 1 investigations are summarized in a memo report addressed jointly to the Executive Director, Water Resources Branch, Manitoba Natural Resources and the Director, Development Service, PFRA. The report concluded that two operating scenarios warranted further study. The first, named "Modified Base", is a scenario where the reservoir operating rules are modified by increasing the winter target pool elevation, with no modifications to the spillway control structure. The second, named "Gated 1", is a scenario that would modify operating rules through the control of flood flows with the use of gates added to the existing chute spillway structure. The existing uncontrolled chute spillway crest section is shown in Figure 1.

Participation by PFRA in the Phase II study was approved by the Director on February 7, 1991. After discussions with Manitoba Regional Division, Design Division's role in the Phase II study was to investigate and report on the "Gated 1" scenario, and to provide technical assistance to Manitoba Regional, where required, in preparation of the Phase II report.

The proposed operating rules for the "Gated 1" scenario, based on the Phase I investigations, indicated that for flood events less than or equal to the 1:10 spring (1:100 summer) event, leaving the gates closed and allowing discharge over the top of the gates would produce the least downstream discharge while maintaining the reservoir rise within

acceptable limits. For spring floods above this level and less than or equal to the 1:100 event, an undershot type gate (radial or vertical lift) operated to maintain reservoir elevation at the top of the gate would provide the best combination of reservoir rise and downstream flow. Floods in excess of the 1:100 spring (1:100 summer) event would be passed with the gates removed from the flow, that is, with an uncontrolled crest. Gates on the spillway would then be used to control downstream releases during flood stage rather than impound water during normal operations. Thus, no stoplogs for maintenance purposes, ice control systems or stringent gate sealing mechanisms are required.

This report contains the results of investigations carried out for modifying the existing spillway control structure to incorporate control gates. Radial gates, vertical lift gates, inflatable rubber dams and drop leaf gates were investigated. Each option was investigated at a preliminary level, and a cost estimate prepared.

The preliminary investigation included an assessment of both the structural and hydraulic feasibility of each option. The preliminary structural analysis of the gates entailed the sizing of the primary horizontal and vertical members and the skin plate for a loading condition where the gates were assumed to be closed and the reservoir at top of dam. The resultant gate weight was calculated and used to verify the approximate gate weight provided by suppliers who quoted both estimated gate weight and cost. Hydraulic analysis was based on the characteristics of individual gate types, and their effects on the discharge characteristics of the existing uncontrolled ogee spillway crest.

## 2. Radial Gate Option

### 2.1 General

The proposed modification of the spillway crest section to accommodate radial gates is shown on Figure 2. Standard design practice for a new structure would be to place the gates at the centerline of the crest, and accommodate the lifting of the gates beneath the road bridge, or locate the road bridge upstream or downstream of the gates. However, the existing structure layout at Shellmouth Dam precluded this type of layout, as such a design would require a substantial change in the horizontal and vertical alignment of the highway bridge. Therefore, the gates are located downstream of the crest.

This configuration requires pier extension downstream of the crest to accommodate the gate trunnion, and upstream of the crest to accommodate new highway bridge girders. As indicated on the figure, the existing downstream bridge girder and cantilevered sidewalk section would be removed, and new bridge girders placed upstream, thus relocating the centerline of the bridge upstream. This modification is required in order to permit the gates to be fully opened.

The existing spillway bays are 15.24 m wide. A single radial gate spanning this width would produce disproportionately large thrust forces at the trunnions and require relatively heavy horizontal beams to carry the moments generated by the large span and limit the resulting gate deflections. In order to reduce forces and other undesirable characteristics, the proposed design incorporates intermediate piers, which results in gates 7.16 m wide by 2.2 m high. The proposed shorter span between piers also allows the use of standard precast bridge girders in the design.

The radial gates were sized and located such that at the spillway design flood event (approximately the 1:1000 flood) the gates could be raised to a height that would completely remove them from the flow. Conventional wire rope hoists are incorporated in the design and a steel operating and maintenance bridge is provided above the gates.

The estimated cost of the radial gate option is \$1,950,000.00, as shown in Table 1. These costs have been developed from past PFRA experience, suppliers quotations and cost estimating tables.

## 2.2 Advantages

Based on comparison with the other alternatives investigated, the radial gate option would have the following advantages :

1. The incorporation of intermediate piers into the design results in the requirement for 8 gates. This option would allow for a higher degree of flexibility in the control of flows than an option with 4 gates, due to the available combination of gates.
2. Reduced spans resulting from the use of intermediate piers allow for economical bridge replacement.

## 2.3 Disadvantages

Based on comparison with the other alternatives investigated, the radial gate option would have the following disadvantages :

1. The proposed design requires the construction of intermediate piers. As well, modifications to the existing piers will be required to carry the thrust forces transferred from the gates to the trunnions.
2. The horizontal alignment of the highway bridge would be adjusted approximately 3.7 m upstream, to accommodate the gate hoisting mechanisms. This would require extensive earthwork. The resulting highway realignment would cause increased traffic risk, which would have to be mitigated by a requirement for reduced traffic speeds.
3. The requirement for additional piers reduces the effective crest length, thereby reducing the hydraulic capacity of the structure.



4. Due to the downstream alignment of the gates, the overall height of the gates is approximately 2.2 m, which is 0.4 m more than the 1.8 m height required for the vertical lift gates.



### 3. Vertical Lift Gate Option

#### 3.1 General

The proposed modification of the spillway crest section to accommodate vertical lift gates is shown on Figure 3. In order to minimize the cost of the gates and hoisting structure, the gates are located at the centerline of the crest. Due to the height requirements of the hoisting system, the existing highway bridge would be modified by removing the centre girder and both curbs. New girders would be added to the outside of each lane, supported by extensions to the existing piers, the result being a divided, single lane (each way) bridge with the gate hoisting structure located in the centre.

In order to decrease the hoisting loads, gate horizontal beam size and/or deflections and simplify fabrication and shipping of the gates, the proposed design incorporates intermediate piers, resulting in a gate span of 7.16 m and a gate height of 1.83 m.

The hoisting superstructure is sized to allow the gates to be totally removed from the flow during the spillway design flood, as well as to allow total removal of the gates for maintenance purposes. Wire rope hoists are incorporated in the design in order to reduce the estimated cost of the installation.

The pier corbels were sized to accommodate the required bridge girders and a standard (CSA CS-600) 600 kN truck load. The pier structure was analyzed for stability, to ensure that eccentric loads would not cause overturning or excessive stresses in the pier.

The estimated cost of the vertical lift gate option is \$1,950,000.00, as shown in Table 2. These costs have been developed from past PFRA experience, suppliers quotations and cost estimating tables.

### 3.2 Advantages

Based on comparison with the other alternatives investigated, the vertical lift gate option would have the following advantages :

1. The incorporation of intermediate piers into the design results in the requirement for 8 gates. This option would allow for a higher degree of flexibility in the control of flows than an option with 4 gates, due to the available combination of gates.
2. The required bridge modifications are simplified and more economically achieved due to the use of intermediate piers.

### 3.3 Disadvantages

Based on comparison with the other alternatives investigated, the vertical lift gate option would have the following disadvantages :

1. The highway bridge would be modified from its existing configuration to a single lane (each way) divided bridge in order to accommodate the gate hoisting mechanisms near the centerline of the existing bridge. This would require a revision in the existing horizontal alignment of the approaches, requiring extensive earthwork, and reduced traffic speeds with increased risk.
2. The proposed design requires the construction of intermediate piers, in order to reduce hoisting loads and simplify gate fabrication and shipping. As well, modifications to the existing piers are required to support the highway bridge and provide gate operating slots.
3. The requirement for additional piers reduces the effective crest length, thereby reducing the hydraulic capacity of the structure.

## 4. Rubber Dam Option

### 4.1 General

The proposed modification of the spillway crest section to accommodate rubber dams is shown on Figure 4. The rubber dams are basically tubes with a thick rubber skin, inflated with low air pressure (20 kPa) to provide a crest control structure between each pier. The rubber skin would be 15.5 mm thick, and is composed of laminations of nylon and EPDM (Ethylene Propylene Diene Monomer) compounded rubber, combined using a press-cure method. A rubber dam would be fitted between each set of piers and would have its own independent set of inflation and deflation controls. Only minor crest modifications would be required to install the rubber dams, which would be fastened down to epoxy grouted anchor bolts by a metal strip at the upstream edge of the crest. Spacer pipes are placed inside each dam near the upstream edge, in order to ensure complete deflation of the dam.

A standard rubber dam design allows for overtopping up to 40% of the dam height. Based on this design criteria the rubber skin would need to be only 12 mm thick. However, the "Gated 1" operating scenario calls for discharge over the rubber dam in excess of 40% of the dam height. The proposed 15.5 mm thick rubber skin would allow overtopping to approximately 110% of the dam height, as required in the "Gated 1" operating conditions.

Rubber dams are control structures that are normally used in the fully upright (closed) or prone (open) positions only. The proposed operating rules for the "Gated 1" scenario call for operation during events above the 1:10 and up to the 1:100 frequency whereby the reservoir elevation is controlled by opening the gate in increments, such that the reservoir elevation is maintained at top of gate. The rubber dams could be used to provide a similar type of control by being partially deflated, thereby controlling reservoir elevation and discharge. The manufacturer has indicated that operation under partially inflated conditions will not cause any structural distress, and should not cause any dam oscillation and related wear problems that can not be accommodated within the proposed design.

A control house containing a control panel, air compressor, piping to each of the dams and an automatic deflation system would be required. This building would be approximately 15 m<sup>2</sup>, and would be constructed adjacent to the spillway. Some modifications to the

existing piers and wingwalls would be required to accommodate the inflation and deflation piping. The control panel would include a system for controlling inner pressure (SCIP system), which monitors the internal pressure of the dam and automatically turns on the compressor upon detecting a pressure drop. This system insures that the dam will always maintain its upright posture.

The rubber dam has been utilized in Japan, Norway and the USA to increase the height of existing structures, primarily for hydropower installations. According to the manufacturer's literature, these installations have performed as designed, and do not have operational problems, even when covered with ice or operated at extremely low winter temperatures.

The estimated cost of the rubber dam option is \$1,500,000.00, as shown in Table 3. These costs have been developed from past PFRA experience, suppliers quotations and cost estimating tables.

#### 4.2 Advantages

Based on comparison with the other alternatives investigated, the rubber dam option would have the following advantages :

1. No intermediate piers are required. This reduces the capital cost, and does not substantially alter the hydraulic capacity from that of the existing structure.
2. Compared to the drop leaf gate alternative, the rubber dam would be continuous between piers. This would provide for a leak free raising of reservoir level to 1.8 m above the existing crest elevation, if such a requirement were deemed necessary in the future.
3. The rubber dam is flexible and therefore can accommodate minor shifts in foundation and sidewall alignment without leaking or maintenance.
4. Due to the flexible nature of the rubber dam, the manufacturer claims that "laboratory and field evaluations have shown that it has superior resistance to wear and damage from rocks and boulders." Also, the rubber dam should not be damaged



from floating logs, as these will either be trapped on the upstream side of the dam and removed by hand or passed when the dam is deflated. As the dam lays flat when deflated, the probability of damage from floating debris is minimal.

5. Maintenance requirements are lower than those of steel gates and hoisting systems, which require periodic painting and lubrication.

6. The automatic deflation system operates without an operator and requires no electric power, and therefore is more reliable than the hoisting mechanisms of the other three proposed gate options.

7. Spillway capacity is maintained at its maximum design level should difficulties be experienced in inflating the dams, and deflation of an inflated dam in the event of an emergency is not dependent on external power. This is an advantage over the radial and vertical lift gates, as failure of the lifting mechanisms for these alternatives would result in a decreased spillway capacity.

8. No modifications to the highway bridge are required to accommodate the rubber dam.

#### 4.3 Disadvantages

Based on comparison with the other alternatives investigated, the rubber dam option would have the following disadvantages :

1. The manufacturer "estimates the serviceability for its rubber dam to be over 30 years". Rubber dams of this type have been in service since 1978, under varying climatic conditions with no apparent degradation; however, their long term performance has not yet been proven. Anticipated life of the steel gate proposals , with standard maintenance, would be in excess of 50 years.

2. A rubber dam is susceptible to vandalism, as are any of the gated options presented. However, the impact of bullet holes and knife cuts is more serious for the rubber dam than the other alternatives. Holes from bullets are minor, and the SCIP

system will keep the dam inflated until the holes are repaired with a plug. Knife cuts are more serious, and could cause dam deflation. The threat of vandalism should be fully assessed if the rubber dam is selected as the best option for the "Gated 1" scenario.

3. The proposed operating rules for the "Gated 1" scenario call for control of the flow by the gates during certain flood events. The manufacturer has indicated that this may be accomplished by partial deflation of the dams. Further investigations and testing would be required to confirm that flow over the partially deflated dams would provide satisfactory hydraulic and structural performance.

## 5. Drop Leaf Gate Option

### 5.1 General

The proposed modification of the spillway crest section to accommodate drop leaf gates is shown on Figure 5. The gates are bottom hinged steel fabricated panels with a remotely controlled hydraulic lifting and lowering system. Two hydraulic cylinders per gate would be required. The gates would have skin plates shaped to the existing ogee crest shape in order to provide the existing hydraulic capacity when the gates are fully lowered into their recesses in the crest section.

In order to facilitate fabrication and shipping, the gates would be 7.62 m wide and 2.13 m high. This would provide two gates per existing bay, for a total of 8 gates. As the purpose of the gates is to provide some flood attenuation for more frequent events, a seal between the gates which would eliminate leakage is not required. That is, leakage between the gates during flooding is not important, as the design FSL is at the bottom of the gates. Therefore, intermediate piers are not provided.

In order to eliminate the need for a hoisting superstructure and provide unimpeded flow when the gates are open (down), a hydraulic hoisting system was selected. This system was designed to maintain the gates in the closed position for the maximum water level given in the "Gated 1" scenario for passage of flood events up to and including the 1:10 spring flood in the sharp-crest (gate closed; discharge over gate) mode of operation. To minimize damages caused by both upstream and downstream flooding for events greater than the 1:10 flood, the gates would be lowered to control reservoir levels and downstream releases. In the event that the required gate operations do not take place at flows higher than the 1:10 flood, loads on the hydraulic cylinders would gradually increase beyond designed values, causing a pressure sensitive bypass valve to open which would result in the gates opening. This allows a reasonable sizing of the hoisting mechanism, as well as providing a measure of operational safety at higher flood flows.

A control house containing a control panel, hydraulic compressor and valving and hydraulic lines to the hoisting cylinders would be required. This building would be approximately

15 m<sup>2</sup>, and would be constructed adjacent to the spillway. Some modifications to the existing piers and wingwalls would be required to accommodate the hydraulic lines.

The estimated cost of the drop leaf gate option is \$910,000.00, as shown in Table 4. These costs have been developed from past PFRA experience, suppliers quotations and cost estimating tables.

## 5.2 Advantages

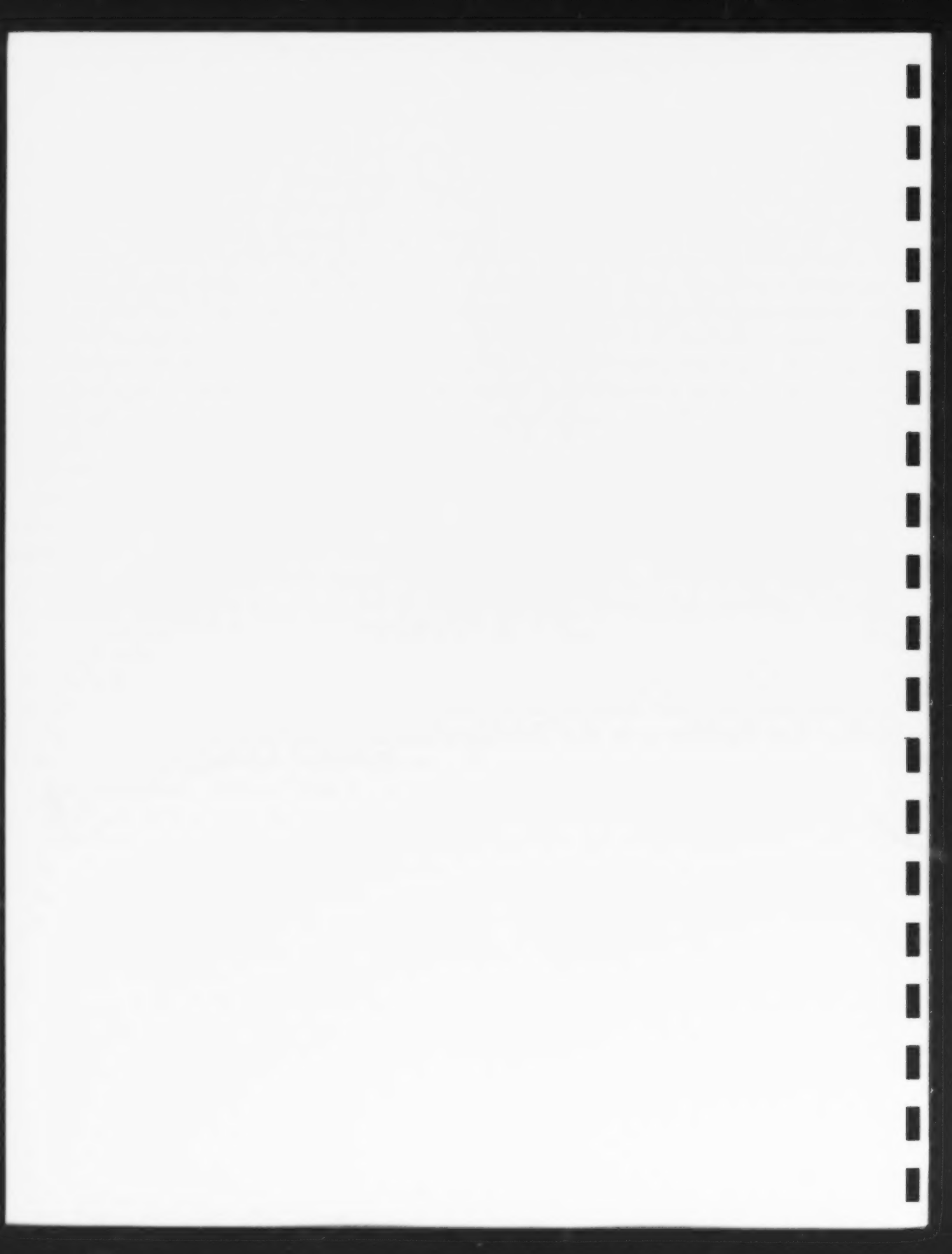
Based on comparison with the other alternatives investigated, the drop leaf gate option would have the following advantages :

1. The proposed design calls for 8 gates. Therefore, this option would allow for a higher degree of flexibility in the control of flows than an option with 4 gates, due to the available combination of gates.
2. Two gates would be installed in each existing spillway bay. As the proposed operating rules call for the FSL to be at the bottom of the gates, no seals are required between the gates. Intermediate piers are not required for support or anchorage of the gates.
3. The hydraulic hoisting mechanisms are designed to support the gate with only a minimal amount of overtopping. This feature of the design will cause the gate hoisting mechanism to fail to the lowered position as discharge over the gates increases above the design limit. Therefore, there would be no decrease in spillway capacity due to a failure in the hoisting mechanisms. This is an advantage over the radial and vertical lift gates, as failure of the lifting mechanisms for these alternatives would result in a decreased spillway capacity.

### 5.3 Disadvantages

Based on comparison with the other alternatives investigated, the drop leaf gate option would have the following disadvantages :

1. No seals are provided between adjoining gates, as the proposed operating rules call for the FSL to be at the bottom of the gates. This would preclude any future increase in FSL above the bottom of the gates without modifications to the gating system, including joining the two gates, providing seals and modifying the hydraulic system to make four cylinders act in unison. The other options considered would not incur this additional expense if a decision in the future were made to increase FSL above the bottom of the gates.
2. The gates operate by dropping into a recess in the crest. The recess must remain free of ice and debris in order for the gates to open fully. This will require some additional design considerations and/or maintenance not required for the other gated options.
3. The hoisting mechanism is powered by a high pressure hydraulic system. The operation and maintenance of such a system is more complex than that of the other options investigated.





## 6. Summary

The preliminary study investigated the feasibility of incorporating control gates into the existing uncontrolled ogee spillway crest on Shellmouth dam. Hydraulic and structural analysis were carried out for 4 options : radial gates, vertical lift gates, rubber dams and drop leaf gates. All the investigated options are technically feasible, and would provide some form of control of reservoir level and discharge during the passage of flood flows. The estimated cost of each alternative, including 30% contingencies, are given below.

| OPTION              | ESTIMATED COST |
|---------------------|----------------|
| RADIAL GATES        | \$1,950,000.00 |
| VERTICAL LIFT GATES | \$1,950,000.00 |
| RUBBER DAMS         | \$1,500,000.00 |
| DROP LEAF GATES     | \$ 910,000.00  |

Clearly, the drop leaf gate option is the most desirable from an economic viewpoint. From a technical viewpoint, it also is the most desirable, as indicated in the force field analysis presented in Table 5.

In conclusion, we would recommend that drop leaf gates be given further consideration as the most practical option for gating the Shellmouth spillway structure, and that operation of these gates be investigated through reservoir simulation to assess the operating rules proposed for the "Gated 1" scenario of the Phase 1 report. The estimated cost of incorporating the gates into the existing structure would be approximately \$910,000.00, excluding engineering costs.

TABLE 1

RADIAL GATE OPTION - COST ESTIMATE

| No.                         | Item                              | Units          | Quantity | Unit Cost | Extension       |
|-----------------------------|-----------------------------------|----------------|----------|-----------|-----------------|
| 1.                          | Radial Gates & Hoisting Mechanism | ea             | 8        | 90,000.00 | 720,000.00      |
| 2.                          | Gate Hoisting Superstructure      | lump sum       | 1        | 35,000.00 | 35,000.00       |
| 3.                          | Embedded Parts                    | lump sum       | 1        | 80,000.00 | 80,000.00       |
| 4.                          | Gate Installation                 | lump sum       | 1        | 25,000.00 | 25,000.00       |
| 5.                          | Concrete Demolition               | m <sup>3</sup> | 130      | 250.00    | 32,500.00       |
| 6.                          | Reinforced Concrete               | m <sup>3</sup> | 450      | 600.00    | 270,000.00      |
| 7.                          | Pier Reinforcing                  | lump sum       | 1        | 25,000.00 | 25,000.00       |
| 8.                          | Precast Bridge Girders            | ea             | 32       | 3,000.00  | 96,000.00       |
| 9.                          | Installation of Bridge Girders    | lump sum       | 1        | 50,000.00 | 50,000.00       |
| 10.                         | Walkway and Curbs                 | lump sum       | 1        | 70,000.00 | 70,000.00       |
| 11.                         | Highway Relocation                | lump sum       | 1        | 90,000.00 | 90,000.00       |
| SUBTOTAL                    |                                   |                |          |           | \$ 1,493,500.00 |
| CONTINGENCIES (APPROX. 30%) |                                   |                |          |           | \$ 456,500.00   |
| TOTAL                       |                                   |                |          |           | \$ 1,950,000.00 |

TABLE 2

VERTICAL LIFT GATE OPTION - COST ESTIMATE

| No. | Item                                | Units          | Quantity | Unit Cost                   | Extension       |
|-----|-------------------------------------|----------------|----------|-----------------------------|-----------------|
| 1.  | Vertical Gates & Hoisting Mechanism | ea             | 8        | 75,000.00                   | 600,000.00      |
| 2.  | Gate Hoisting Superstructure        | lump sum       | 1        | 95,000.00                   | 95,000.00       |
| 3.  | Embedded Parts                      | lump sum       | 1        | 230,000.00                  | 230,000.00      |
| 4.  | Gate Installation                   | lump sum       | 1        | 25,000.00                   | 25,000.00       |
| 5.  | Concrete Demolition                 | m <sup>3</sup> | 100      | 250.00                      | 25,000.00       |
| 6.  | Reinforced Concrete                 | m <sup>3</sup> | 290      | 600.00                      | 174,000.00      |
| 8.  | Precast Bridge Girders              | ea             | 32       | 3,000.00                    | 96,000.00       |
| 9.  | Installation of Bridge Girders      | lump sum       | 1        | 50,000.00                   | 50,000.00       |
| 10. | Walkway and Curbs                   | lump sum       | 1        | 125,000.00                  | 125,000.00      |
| 11. | Highway Relocation                  | lump sum       | 1        | 90,000.00                   | 90,000.00       |
|     |                                     |                |          | SUBTOTAL                    | \$ 1,510,000.00 |
|     |                                     |                |          | CONTINGENCIES (APPROX. 30%) | \$ 440,000.00   |
|     |                                     |                |          | TOTAL                       | \$ 1,950,000.00 |

TABLE 3

RUBBER DAM OPTION - COST ESTIMATE

| No. | Item                                                | Units    | Quantity | Unit Cost                   | Extension       |
|-----|-----------------------------------------------------|----------|----------|-----------------------------|-----------------|
| 1.  | Supply of Rubber Dams                               | ea       | 4        | 250,000.00                  | 1,000,000.00    |
| 2.  | Installation of Rubber Dams<br>and Associated Works | lump sum | 1        | 120,000.00                  | 120,000.00      |
| 3.  | Control Building and Works                          | lump sum | 1        | 40,000.00                   | 40,000.00       |
|     |                                                     |          |          | SUBTOTAL                    | \$ 1,160,000.00 |
|     |                                                     |          |          | CONTINGENCIES (APPROX. 30%) | \$ 340,000.00   |
|     |                                                     |          |          | TOTAL                       | \$ 1,500,000.00 |

TABLE 4

DROP LEAF GATE OPTION - COST ESTIMATE

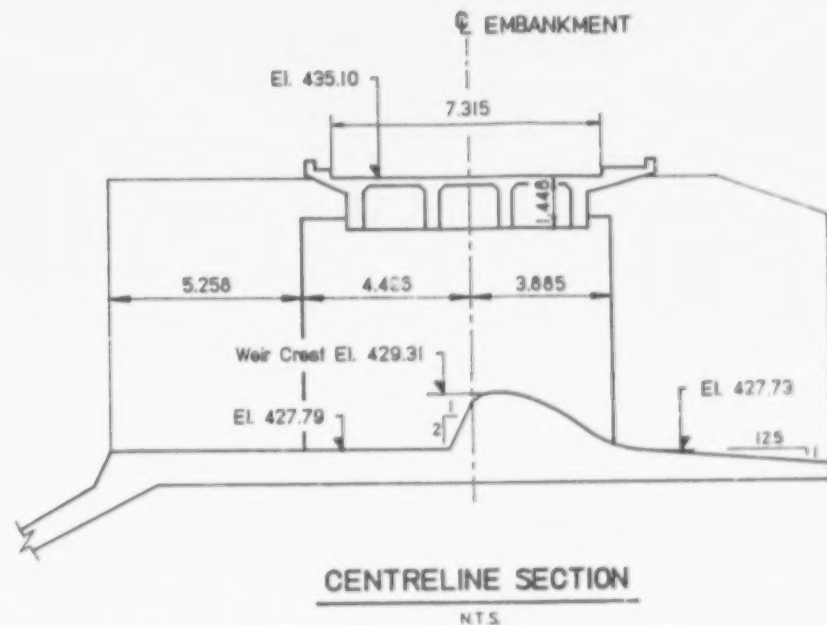
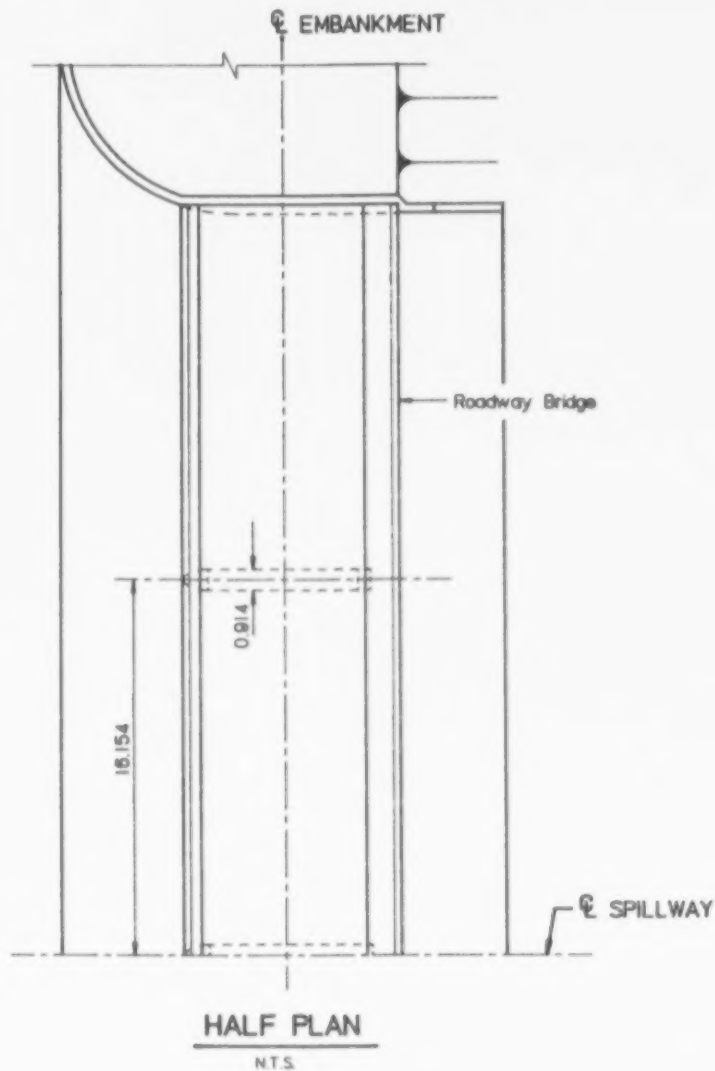
| No. | Item                         | Units    | Quantity | Unit Cost                   | Extension     |
|-----|------------------------------|----------|----------|-----------------------------|---------------|
| 1.  | Drop Leaf Gates              | ea       | 8        | 40,000.00                   | 320,000.00    |
| 2.  | Hydraulic Cylinders          | ea       | 16       | 6,000.00                    | 96,000.00     |
| 3.  | Gate & Cylinder Installation | lump sum | 1        | 25,000.00                   | 25,000.00     |
| 4.  | Crest Modifications          | lump sum | 1        | 200,000.00                  | 200,000.00    |
| 5.  | Control Building and Works   | lump sum | 1        | 60,000.00                   | 60,000.00     |
|     |                              |          |          | SUBTOTAL                    | \$ 701,000.00 |
|     |                              |          |          | CONTINGENCIES (APPROX. 30%) | \$ 209,000.00 |
|     |                              |          |          | TOTAL                       | \$ 910,000.00 |

TABLE 5

SPILLWAY CONTROL GATE OPTIONS - FORCE FIELD ANALYSIS

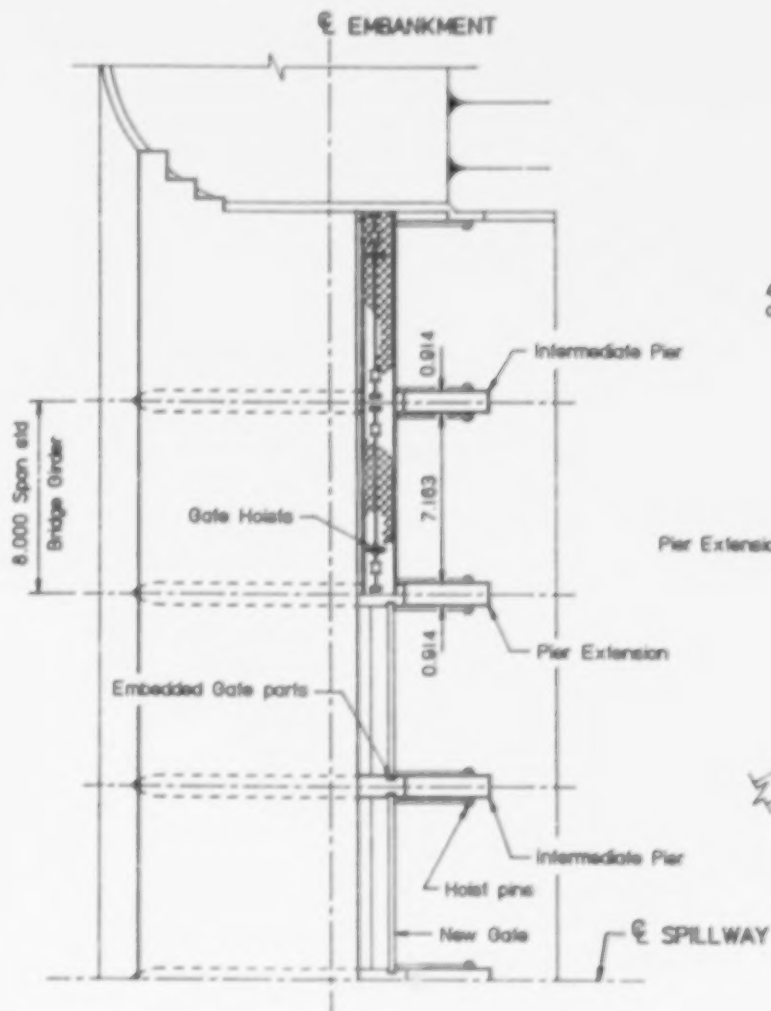
| Item                                        | Radial Gates |    | Vertical Lift Gates |    | Rubber Dams |    | Drop Leaf Gates |    | Comments                                                                                                               |
|---------------------------------------------|--------------|----|---------------------|----|-------------|----|-----------------|----|------------------------------------------------------------------------------------------------------------------------|
| Hydraulic capacity                          |              | -  |                     | -  | +           |    | +               |    | Intermediate piers reduce capacity.                                                                                    |
| Impact of hoisting mechanism failure        |              | -  |                     | -  | +           |    | +               |    | Failure causes reduction in discharge capacity for radial, vertical lift gates.                                        |
| Regulation of flow by gates                 | +            |    | +                   |    |             | -  | +               |    | Rubber dam designed as fully open or fully closed only.                                                                |
| Control of floods<br>> 1:10 < 1:100         | +            |    | +                   |    |             | -  |                 | -  | Same control can be obtained for overflow gates as for undershot gates, but gate operating rules need to be developed. |
| Automatic operation                         |              | -  |                     | -  | +           |    | +               |    | Rubber dam and drop leaf gate designs incorporate automatic mechanical opening system.                                 |
| Impact on existing structure                |              | -  |                     | -  | +           |    | +               |    | Radial & vertical lift gates require substantial modifications and highway relocation.                                 |
| Design life                                 | +            |    | +                   |    |             | -  | +               |    | Rubber dam has 30 year design life.                                                                                    |
| Operation and maintenance                   |              | -  |                     | -  | +           |    |                 | -  | Rubber dam O&M is small in comparison with that required for steel gates.                                              |
| Vandalism                                   | +            |    | +                   |    |             | -  | +               |    | Rubber dam susceptible to extreme damage by vandalism.                                                                 |
| Future increase in FSL above existing crest | +            |    | +                   |    | +           |    |                 | -  | Adjoining drop leaf gates do not incorporate seals.                                                                    |
| TOTALS                                      | 5+           | 5- | 5+                  | 5- | 6+          | 4- | 7+              | 3- |                                                                                                                        |



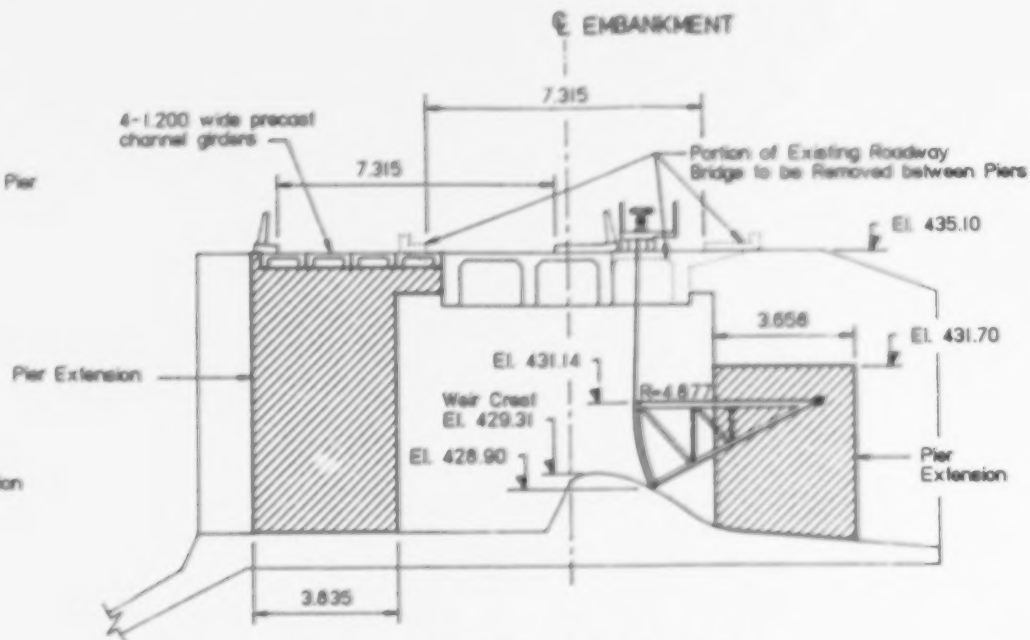


|                                                                   |                                                                                                                |                                                                                                                                                      |                                                                                                                                                                       |
|-------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Drawn: <i>PJK</i><br>Date: <i>JAN 1992</i><br>Checked: <i>WCS</i> | Submitted: <i>RE MEMORABLE</i><br>Date: <i>JAN 1992</i><br>Approved: <i>[Signature]</i><br>Date: <i>2/1/92</i> | Agriculture Canada<br>Project: <i>Administration du Développement agricole des Prairies</i><br>Administration du Développement agricole des Prairies | SHELLMOUTH RESERVOIR STUDY<br>PRELIMINARY STUDY OF SPILLWAY CONTROL GATES<br>EXISTING SPILLWAY CREST<br>AS CONSTRUCTED<br>Scale: N.T.S. Date: JAN/92 Sheet No: 117021 |
|-------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|

FIGURE 1

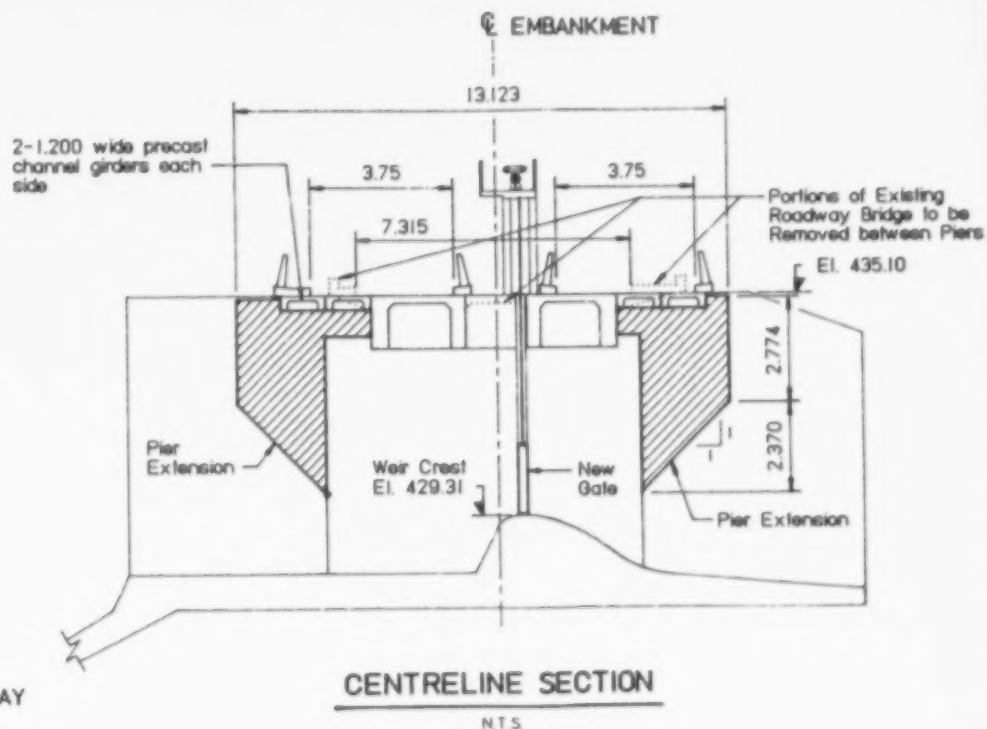
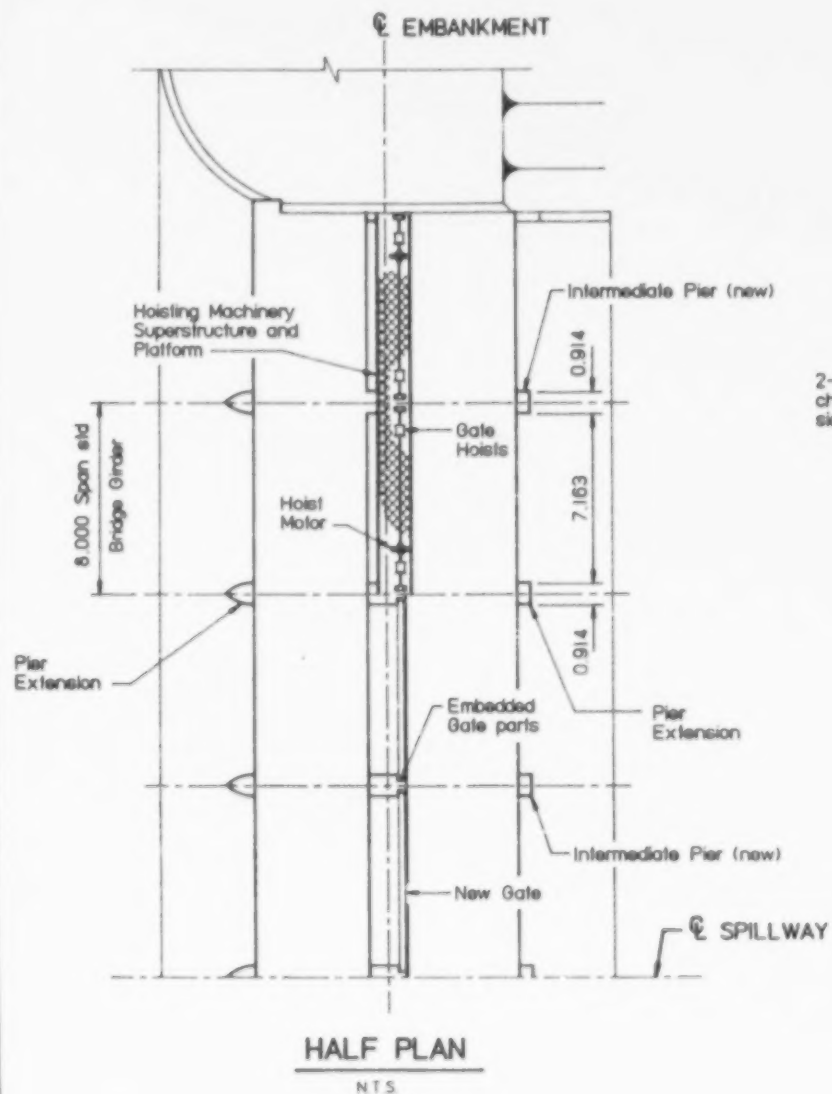


**HALF PLAN**  
N.T.S.

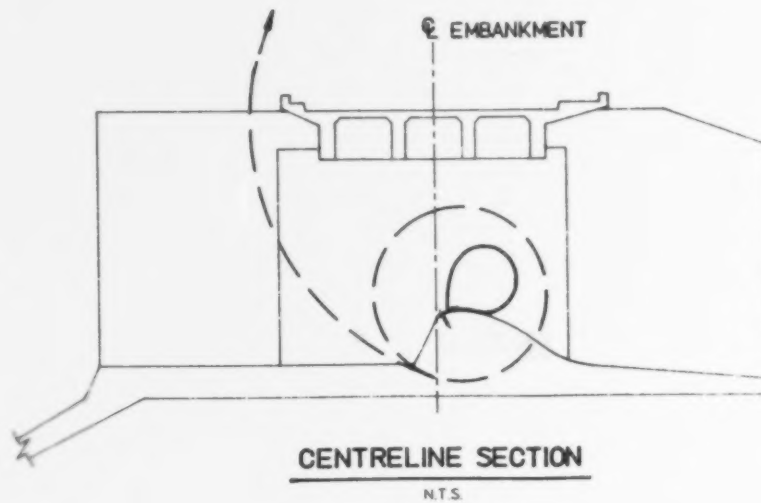
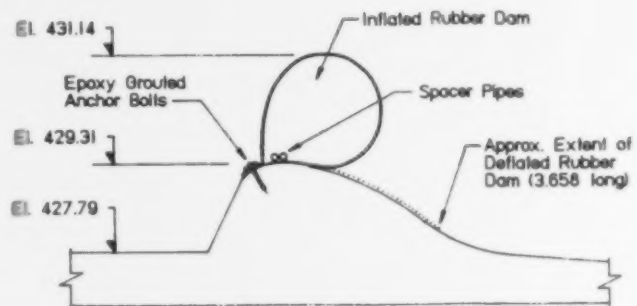
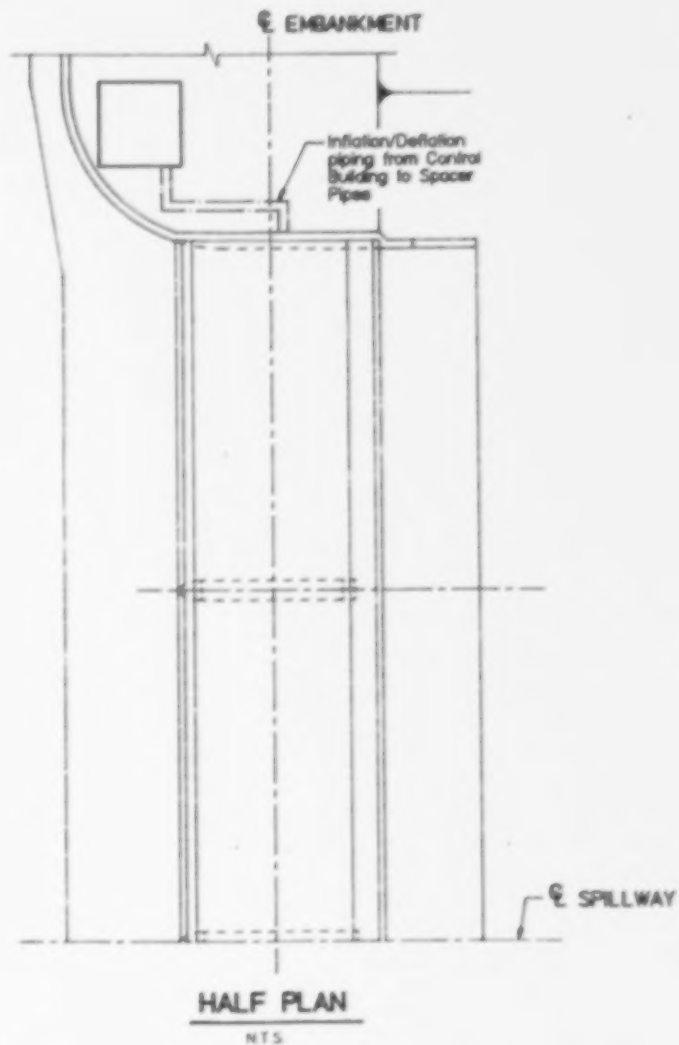


**CENTRELINE SECTION**  
N.T.S.

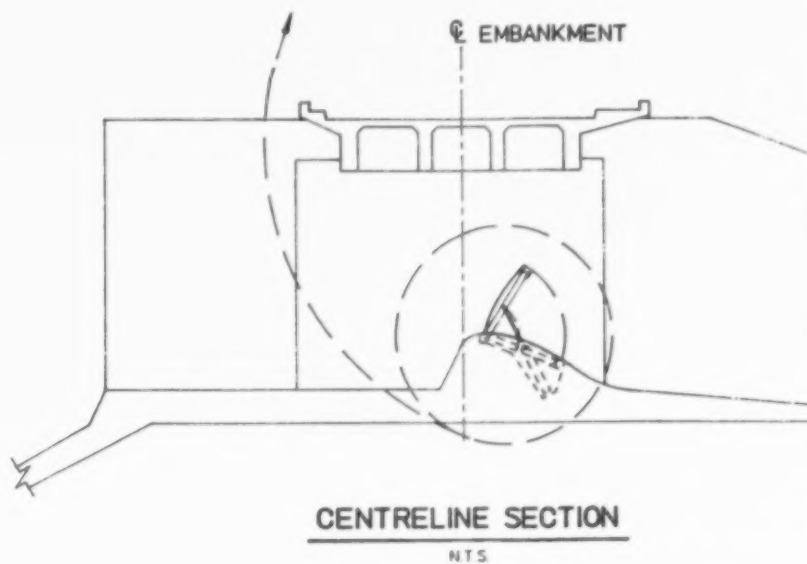
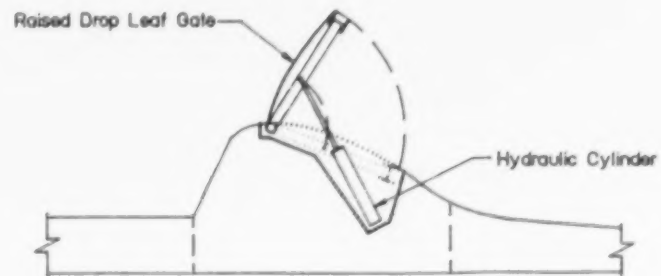
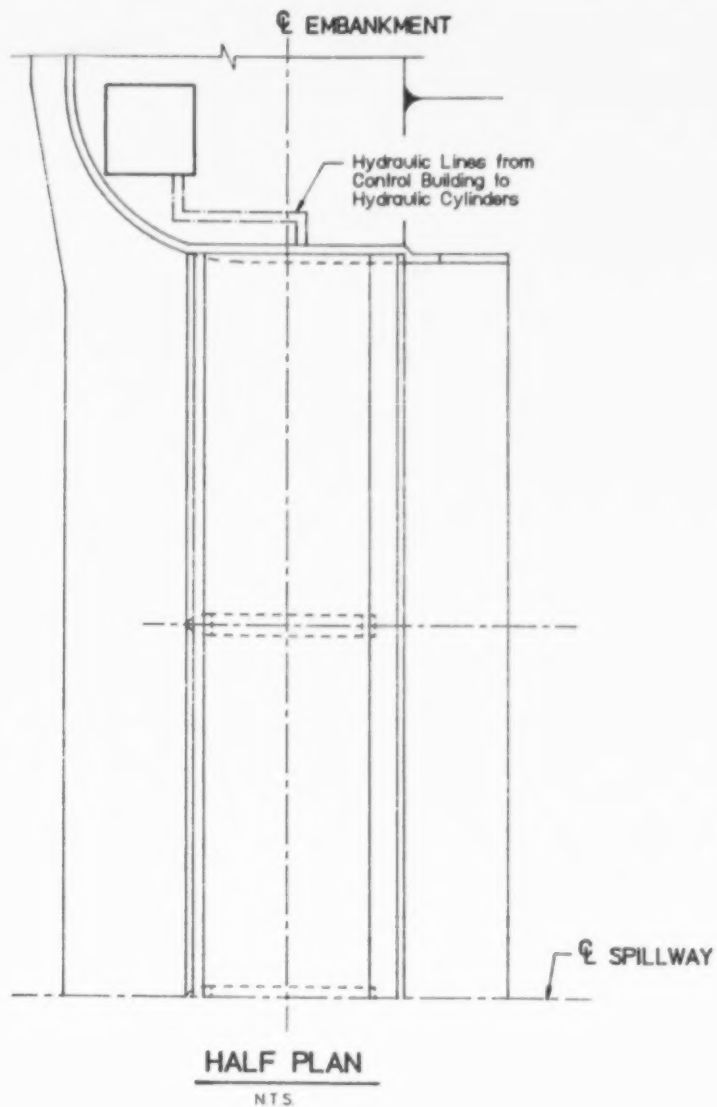
|                                                                                  |               |                                                                                                              |                                                                                                                          |                                                                                                                                                  |
|----------------------------------------------------------------------------------|---------------|--------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| Project: <b>PJA</b><br>Drawn: <b>A. J. [Signature]</b><br>Checked: <b>H.C.S.</b> |               | Revision: <b>RR 45-000000</b><br>Date: <b>June 1982</b><br>Drawn: <b>[Signature]</b><br>Date: <b>4/26/82</b> | Prepared by: <b>Consultants Inc.</b><br>Reviewed by: <b>Management Systems</b><br>Approved by: <b>Management Systems</b> | <b>SPILLWAY RESERVOIR STUDY</b><br><b>PRELIMINARY STUDY OF SPILLWAY CONTROL GATES</b><br><b>CREST MODIFICATIONS</b><br><b>RADIAL GATE OPTION</b> |
| Scale: N.T.S.                                                                    | Date: JUNE 82 | Drawn: H7022                                                                                                 | FIGURE 2                                                                                                                 |                                                                                                                                                  |



|                            |  |                                   |  |                                                                              |  |                                                                    |  |
|----------------------------|--|-----------------------------------|--|------------------------------------------------------------------------------|--|--------------------------------------------------------------------|--|
| Designed<br><b>PJK</b>     |  | Reviewed<br><b>CE. HAINBARBER</b> |  | Agriculture<br>Canada                                                        |  | SHELLMOUTH RESERVOIR STUDY                                         |  |
| Drawn<br><b>J. L. L...</b> |  | Date<br><b>Jan 1988</b>           |  | Phase Form<br>Administration de<br>Recherches et<br>Développement des Pêches |  | PRELIMINARY STUDY OF SPILLWAY CONTROL GATES<br>CREST MODIFICATIONS |  |
| Checked<br><b>W.C.S.</b>   |  | Date<br><b>22/01/88</b>           |  | Development Service                                                          |  | VERTICAL LIFT GATE OPTION                                          |  |
|                            |  |                                   |  |                                                                              |  | Scale<br>N.T.S.                                                    |  |
|                            |  |                                   |  |                                                                              |  | Date<br>JAN/92                                                     |  |
|                            |  |                                   |  |                                                                              |  | NPN 96<br>11/1023                                                  |  |
|                            |  |                                   |  |                                                                              |  | <b>FIGURE 3</b>                                                    |  |



|                                                                             |  |                                                                                                                  |  |                                                                                                                            |  |                                                                                                                       |  |
|-----------------------------------------------------------------------------|--|------------------------------------------------------------------------------------------------------------------|--|----------------------------------------------------------------------------------------------------------------------------|--|-----------------------------------------------------------------------------------------------------------------------|--|
| Designed: <b>R.J.K.</b><br>Drawn: <b>J. J. J.</b><br>Checked: <b>H.C.S.</b> |  | Submitted: <b>R.R. WEINBERGER</b><br>Date: <b>Jan/92</b><br>Approved: <b>[Signature]</b><br>Date: <b>2-11-92</b> |  | Agriculture Canada<br>Pêche et Pâtisseries<br>Administration du Développement agricole des Prairies<br>Development Service |  | SHELLMOUTH RESERVOIR STUDY<br>PRELIMINARY STUDY OF SPILLWAY CONTROL GATES<br>CREST MODIFICATIONS<br>RUBBER DAM OPTION |  |
| SCALE: N.T.S.                                                               |  | DATE: JAN/92                                                                                                     |  | FIG. NO.: 117024                                                                                                           |  | FIGURE 4                                                                                                              |  |



|                                                                         |  |                                                                                                                                                             |  |                                                                                                                                     |  |                                                                                                                                                                     |  |
|-------------------------------------------------------------------------|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------|--|-------------------------------------------------------------------------------------------------------------------------------------|--|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
| Design: <b>P.J.K.</b><br>Drawn: <b>W.C.S.</b><br>Checked: <b>W.C.S.</b> |  | Submitted: <b>RE WINDERMERE</b><br>Date: <b>JAN/98</b><br>Approved: <b>[Signature]</b><br>On Director: <b>Development Services</b><br>Date: <b>22/11/98</b> |  | Agriculture<br>Canada<br>Programme<br>Administration des<br>Ressources<br>Développement<br>des Programmes<br>Développement Services |  | SHELLMOUTH RESERVOIR STUDY<br>PRELIMINARY STUDY OF SPILLWAY CONTROL GATES<br>CREST MODIFICATIONS<br>DROP LEAF GATE OPTION<br>Scale: NTS DATE: JAN/97 PPS No: 117025 |  |
|-------------------------------------------------------------------------|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------|--|-------------------------------------------------------------------------------------------------------------------------------------|--|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|

FIGURE 5







